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CONTENTS.

PROCEEDINGS

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VOL. XXV.

PAPERS READ BEFORE THE ACADEMY.

I.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XXXIV. — TELEPHONIC SPECIFIC INDUCTIVE CAPACITY.

By F. H. Safford and G. U. G. Holman.

Presented by W. W. Jacques, December 11, 1889.

In a paper on the Construction of Telephone Circuits, read before this Academy on the 15th of June, 1887, by the Electrician of the American Bell Telephone Company, Dr. Jacques, it was pointed out "that the readiness with which telephonic conversation may be carried on over any circuit, whether made up of cables or pole lines, or both, depends, —

"1. On the total electrical resistance of the circuit joining together the two stations.

"2. On the total electrostatic capacity of this circuit."

And the general rule was laid down: —

"No matter what may be the distance between two points, good business conversation may be carried on between them, provided they be connected by a pole line or cable, or both, the product of whose total resistance by its total capacity is less than 2,000, if transmitters of the Blake type be used, and less than 4,500, if transmitters of the Hunnings type be used."

It is evident, therefore, that in the construction of a telephone line it is desirable to reduce both the *resistance* and the *capacity* to a minimum.

In a pole line, since the wire is suspended high above the earth, the capacity is always small, and the resistance is the factor that we must try to keep down.

In cable lines, however, where the conductor is necessarily brought near to other conductors, or a metal shield, or the earth, the capacity becomes quite an important factor to be respected.

In lines made up, as is most generally the case, of a comparatively short section of cable and a larger section of iron pole wire, the capacity of the cable becomes pre-eminently the factor to be respected; for, since the limit of conversation is here determined by the product of the capacity of the cable and the resistance of the whole line, a small percentage of saving in the capacity of the cable gives an enormous gain in the readiness with which conversation may be carried on over the line.

It becomes of vital importance, therefore, to choose an insulating material for telephone cables of low specific inductive capacity.

We have accordingly measured the electrostatic capacity of a considerable number of substances used for insulating wires in cables, and, since the specific inductive capacity for the same insulator is very different for telephone currents from what it is for telegraph currents, because the charge and discharge take place so much more frequently, we have adopted a method and apparatus in which currents of telephonic frequency are used.

This apparatus is a Gordon induction balance, (see Gordon's Electricity and Magnetism, p. 110,) in which the substances were charged and discharged by currents from an induction coil, and the balance was observed with a telephone instead of an electrometer.

With this apparatus, we measured the specific inductive capacity of a considerable number of insulating materials, and each when subjected to various rates of charge.

We found that the capacity varied very materially with the rate of charge, some substances increasing and others decreasing, but no general rule was evolved.

We found that measurements of the capacities of telephone cables made by the ordinary galvanometric measurements gave no indications of the comparative merits of these cables for telephonic work.

Finally, we made an accurate series of measurements of the specific inductive capacity of the following substances, when submitted to

actual telephone currents. The values might perhaps be called the "telephonic specific inductive capacity," leaving the expression "telegraphic specific inductive capacity" to indicate values measured in the old-fashioned way.

TABLE OF SPECIFIC INDUCTIVE CAPACITIES, MEASURED BY TELEPHONE CURRENTS.

Petroleum (Brooks Cable)	1.6
Solid paraffine	2.0
Cotton saturated with paraffine in vacuum (Faraday Cable)	2.0
Cotton boiled in paraffine (Patterson Cable)	2.6
India-rubber	3.7
Artificial gutta-percha (Gwynn)	3.9
Gutta-percha	4.2
Glass	4.6
Water	6.3

An inspection of this table shows that, so far as capacity is concerned, petroleum is the best substance to be used, and doubtless this would be the case were it possible to keep it free from water; but water, we see from the table, has a specific inductive capacity of 6.3, so that its presence in the petroleum raises the capacity from the lowest to the highest in the list.

This observation is borne out by actual experience with "Brooks" cables in telephony. When new, and the petroleum dry, it works excellently; but as water finds its way in, the cable rapidly loses its efficiency for telephonic work.

This action of the water is quite different from its action as a *conductor* to produce leakage, for the loss of electricity due to leakage in a Brooks cable that has lost its efficiency from the presence of moisture is entirely insufficient to account for the deterioration.

Next to petroleum, solid paraffine is seen to be the best substance to use; but on account of mechanical difficulties it has never been found practicable to coat wires directly with solid paraffine.

If the wires are wound with cotton and then boiled in paraffine, as they are in making "Patterson" cables, the specific inductive capacity is raised to 2.6, an increase of 30%, which we have seen is a very great detriment.

If, however, the wires are wound with cotton, and the air and moisture removed by the aid of heat and a vacuum, and they are then boiled in paraffine, from which the air and moisture have also been removed by heat and vacuum, the specific inductive capacity

again falls to 2.0, which is the same as that of solid paraffine. This is the process used in preparing the "Faraday" cable.

It is possible that the inferiority of the Patterson cable as compared with the Faraday is due largely to the moisture retained in the cotton, which we have seen has a capacity of 6.3.

Leaving the paraffine cables, rubber is the next best, then gutta-percha, and poorest of all is glass; but all of these substances have so high a specific inductive capacity as to entirely unfit them for telephonic work.

Rogers Laboratory of Physics,
November, 1889.

II.

ON SOME NORTH AMERICAN SPECIES OF LABOULBENIACEÆ.

By Roland Thaxter.

Presented by W. G. Farlow, February 12, 1890.

Note. — The following is intended as a preliminary communication on American Laboulbeniaceæ, which it is my purpose to supplement as soon as practicable by a more extended account, to form the second part of a proposed monograph of Entomogenous Plants, of which the first, on the Entomophthoreæ of the United States,* has already appeared. Illustrations of the new species described in this paper cannot well be given in the present connection, but will accompany my complete account of the subject when it is published.

The Laboulbeniaceae constitute a small group of fungi, without close affinities among other known Ascomycetes, the members of which are remarkable both in their structure and development, as well as peculiar for their external parasitism upon insects of several orders. Up to the present time little has been recorded concerning them in this country, and the total number of forms at present known represent only fifteen described species. Of these twelve are European, distributed among five genera: *Laboulbenia*, *Stigmatomyces*, *Helminthophana*, *Chitonomyces*, and *Hæmatomyces*. Of the remaining species, two are South American, belonging to the genus *Laboulbenia*, while the single representative of the group as yet recorded from this country has been described as *Appendicularia entomophila* Peck,† a genus, as will be presently noted, synonymous with *Stigmatomyces* Karsten.

Our present knowledge of the group rests chiefly upon the writings of Robin,‡ Karsten,§ and Peyritsch,‖ the first notice of any member

* Memoirs of the Boston Society of Natural History, Vol. IV. No. VI. (1888).

† Thirty-eighth Rep. N. Y. State Mus. of Nat. Hist., p. 95, Plate III. figs. 1–4.

‡ Robin, Hist. Nat. d. Veget. Paras. etc., Paris, 1853, p. 622.

§ Chemismus d. Pflanzenzelle, Wien, 1869, p. 78.

‖ Sitz. d. Kaiserl. Acad. d. Wissensch. Wien, (1871) LXIV Band, 1 Abth., p. 441; (1873) LXVIII Band, 1 Abth., p. 227; (1875) LXXII Band, 3 Abth.

of the family being apparently that of the entomologist Rouget.* The family has, moreover, received attention from a zoölogical point of view, the genus of Vermes, *Arthrorhynchus*, having been founded by Kolenati † on species parasitic upon *Nycteribia* (Dipterous parasites of bats).

The members of the family may be briefly described as consisting usually of a main subclavate, flattened body, which for lack of a better term may be called the *receptacle;* simple, made up of a few large cells and bearing at its distal end one or more perithecia; or compound, the divisions bearing solitary perithecia. Within the perithecia, asci are developed by successive sprouting from basal initial cells. The asci contain apparently eight spores, although this number has been definitely observed in a single species only. The spores, which are hyaline, usually fusiform, once septate, and more or less involved in mucus, are expelled through the elastic apical pore of the perithecium, the ascus wall, as in other well known instances, disappearing before the discharge takes place. The spores become attached by one extremity to the surface of the host, and by subsequent division produce a new individual, without forming hyphæ or a mycelium of any sort. The point by which the spore is attached becomes modified into a dark, horny-looking piece, which penetrates the chitinous integument of the insect, and forms the single medium of nutrition as well as of attachment.

In addition to the perithecium certain other bodies, bearing a definite relation to it, are always present, borne usually on the receptacle close beside the perithecium; in two genera (*Helminthophana* and *Cantharomyces*) arising near the base of the receptacle. These bodies, or appendages, have been called *paraphyses*, or better *pseudoparaphyses;* and are of great morphological as well as systematic importance, varying greatly in the different genera and species. Although certain of these appendages are usually sterile, there seems no reasonable doubt that one of them, at least, is always functional as an antheridium, or more commonly bears certain organs which are functional as antheridia. From these Karsten has observed the production of bodies which he considers antherozoids; but confirmatory observations, other than his own, are lacking.

In *Laboulbenia*, the only genus which the writer has been able to examine with any thoroughness in its different stages, the supposed

* Ann. d. l. Soc. Entomol. d. France, Tom. VIII. p. 21 (1850), sec. Robin.
† Wiener Entomol. Monatschrift, 1857, Band I. p. 66, sec. Peyritsch.

antheridia are always bottle- or flask-shaped, and borne on the pseudoparaphysis next to the perithecium. These peculiar bodies, which appear to have been overlooked by Peyritsch, or whose importance does not seem to have been appreciated by him, arise from the lower septæ of the pseudoparaphyses, or are sometimes terminal on short branches. They are invariably present, as far as the writer's observations indicate, just before fertilization takes place, disappearing as the perithecium matures; so that in the adult plant there is commonly no vestige of them.

Fertilization is accomplished through the medium of a body which must be considered a trichogyne, and is connected directly with the cell from which the asci subsequently arise. The character of the trichogyne varies in different genera, and in *Laboulbenia* may reach a remarkable degree of development, giving rise to branches, the tips of which may be coiled in a definitely spiral manner. The trichogyne is even more short-lived than the supposed antheridia, disappearing as soon as any development is observable in or about the central cell with which it is connected. Whether it is fertilized through the agency of minute round or oval bodies, frequently observed by the writer about the apices of the antheridia, more rarely within them, is quite uncertain, yet the observations of Karsten would point to this conclusion.

It may be mentioned that De Bary did not look upon the sexuality of these fungi with any favor, as may be inferred from his remark* that Peyritsch himself did not think very well of his (Peyritsch's) "attempt to save the trichogyne" by supposing a fertilization through contact with one of the pseudoparaphyses in the genus *Laboulbenia.* That a form of sexual reproduction is present, however, among the species of *Laboulbenia* at least, cannot in the writer's opinion be for a moment doubted by any one who has personally observed the more important stages of their development.

The immediate affinities of these most singular plants are, as has been mentioned, very uncertain; and their resemblance to some of the higher Algæ, through their supposed method of sexual reproduction, is striking and interesting in connection with the aquatic, or semi-aquatic, habit of many of them. That they are fungi, and at the same time Ascomycetous, seems beyond question. Why, therefore, they should be placed by De Bary and others among *doubtful* Ascomycetes, is not apparent.

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* Comp. Morphol. and Biol. of Fungi, etc., English ed., p 275.

In the following descriptions the term *receptacle* has been used to designate the main body of the fungus; the side from which the perithecium springs being spoken of as the *inner*, while that bearing the pseudoparaphyses is spoken of as the *outer*, where this distinction is possible. The first two superposed "stem cells" of the receptacle are spoken of as the *basal* and *supra-basal* cells.

STIGMATOMYCES Karsten (1871).

Stigmatomyces entomophila (Peck).

Appendicularia entomophila Peck, l. c.
Appendiculina entomophila Berlese, Malpighia, Vol. III. p. 59.

Through the kindness of its discoverer, the Rev. J. L. Zabriskie, the writer has been enabled to examine authentic specimens of this interesting and distinct species, which proves to belong without question to the present genus. The antheridial appendage is proportionately somewhat smaller than in its near ally (*S. Baeri* (Knoch) Karst.), but has the same peculiar structure and bears the same relation to the perithecium; and structural differences which could separate it generically are wholly wanting. Berlese in the paper referred to calls attention to the fact that *Appendicularia* has been preoccupied among the *Melastomaceae*, and proposes the substitution of *Appendiculina*, which, however, proves to be needless.

PEYRITSCHIELLA nov. gen.

Receptacle composed of two superposed basal cells, above which it is multicellular, one cell on the inner side forming a short, sharp projection. Perithecium one, sometimes two; when single, terminal, nearly median, subconical, the spreading apex symmetrically four-lobed. Pseudoparaphyses arising from several different points on either side of the receptacle.

Peyritschiella curvata nov. sp.

Characters of the genus. Usually strongly curved, colorless except the large, jet-black piece of attachment, and the bases of the pseudoparaphyses which are also black and strongly constricted in the middle. Paraphyses colorless, cylindrical or subclavate, septate or obscurely septate; arising in three to five groups, each made up of from one to three pseudoparaphyses, and placed alternately at different

points on either side of the receptacle. Total length to tip of perithecium 280–300 μ. Perithecium 90–100 $\mu \times$ 22–29 μ. Spores fusiform, asymmetrically once septate, involved in mucus, 26 $\times$ 4 μ. Pseudoparaphyses sometimes 60 μ in length.

Host, *Platynus cincticollis*. Connecticut.

This genus appears to differ from other known genera in the presence of several groups of paraphyses on both sides of the receptacle. The presence of two perithecia was only observed in a single specimen. The perithecium resembles that of *Helminthophana* in being symmetrical at the apex. The genus is named in memory of the late Dr. Peyritsch, as a slight recognition of his well known and admirable work upon this family.

CANTHAROMYCES nov. gen.

Receptacle simple; or compound above the supra-basal cell, from which one or more divisions may arise, each bearing a solitary perithecium. Pseudoparaphyses, one or more, arising from the supra-basal cell. Perithecium median, tapering towards its symmetrical apex.

Cantharomyces verticillata nov. sp.

Color pale yellowish. Perithecium expanding slightly above its base, then tapering slowly towards its slightly truncate, conical apex. Pseudoparaphyses arising in a whorl of two to four (the number apparently variable) from the small supra-basal cell; simple or branched; once or twice constricted at the septæ; the joints short, stout, and broader towards their rounded apices. A single simple pseudoparaphysis composed of cylindrical segments hardly constricted at the septæ arises also from the distal end of the third stem cell. Receptacle simple, composed of five single superposed cells, arising from a small black piece of attachment, the first four nearly cylindrical, the fifth short, slightly expanded towards the base of the perithecium, which is made up of two or three very small cells. The supra-basal cell is squarish about half the length of the basal. The third and fourth cells are nearly similar, somewhat longer than the basal and supra-basal taken together. Spores fusiform, apparently once septate, and about 18–20 $\mu \times$ 3 μ (these were only examined, however, *within* the perithecium). Perithecia 90–127 $\mu \times$ 18–26 μ. Pseudoparaphyses 50–125 μ. Receptacle 75–125 $\mu \times$ 11 μ.

On *Sunius longiusculus*. Anna, Ill. (S. A. Forbes).

Cantharomyces Blidii nov. sp.

Color yellowish. Perithecia subconical, one or more in number, each borne at the summit of a division of the receptacle arising from the supra-basal cell. Pseudoparaphyses one, rarely more, arising from the supra-basal cell: composed of three superposed basal cells, the second swollen, longitudinally septate; the third squarish, small, surmounted by one or two small cells, from which arise a variable number of slightly curved, septate, slender branches themselves variably once or twice branched. Receptacle simple or compound; the basal and sub-basal cells rather short, the lower and outer portions of the wall of the latter often thickened, deep black, and indented; but sometimes without signs of this modification. The supra-basal cell may give rise to one or more divisions of the receptacle, which are sub-lateral in position, and consist of a long, cylindrical basal cell, surmounted by a broader short cell, divided longitudinally by a median septum, and bearing the perithecium directly. Spores slender, fusiform, involved in mucus, asymmetrically once septate, $25 \times 3.5\ \mu$. Perithecia 92.5–130 $\mu \times$ 33–55 μ, average $114 \times 42\ \mu$. Pseudoparaphyses, total length 90–180 μ, average 150 μ. Total length to tip of perithecia 200–370 μ, average 280 μ.

On *Blidius assimilis*. Champaign, Ill. (S. A. Forbes).

I am greatly indebted to the kindness of Professor Forbes for specimens of the two singular forms above described. The material of *C. verticillata* consisted of but four adult specimens, so that further study may show the presence of a compound receptacle in this species as well as in *C. Blidii*, where it was observed in only a few of the twenty or more individuals examined. The secondary pseudoparaphysis of *C. verticillata* is wholly wanting in *C. Blidii*.

LABOULBENIA Montagne et Robin (1853).

Laboulbenia elongata nov. sp.

Color brown or blackish. Perithecium long-ovoid, darker just below its hyaline apical pore. Pseudoparaphyses arising from a black basal disk; two in number, brown to blackish, sometimes hyaline near their extremities, septate, slightly constricted at the septæ; their basal cells distinct, the inner giving rise immediately to two branches which may be either simple or once or twice dichotomously branched. The outer pseudoparaphysis usually once or twice dichotomously branched

above the supra-basal cell. Receptacle composed of seven main cells; the basal nearly triangular, the supra-basal elongate, cylindrical, often three times as long as the basal. Above the supra-basal cell the receptacle is divided by a longitudinal partition into two cells, that on the inner side smaller, and separated from the base of the perithecium by a single, usually squarish cell, above which are two small triangular cells, an outer and an inner, sometimes connected, which form the base of the perithecium. The two remaining cells of the receptacle bear the disk-like base of the pseudoparaphyses, and consist of an outer larger one, separated by an oblique partition, on its upper inner side, from the smaller inner one. Spores fusiform, hyaline, granular, involved in mucus, septate near one extremity, 75–80 $\mu \times$ 6.5–8 μ. Perithecia 135–170 $\mu \times$ 65–70 μ. Pseudoparaphyses 200–725 μ. Length to tip of perithecium 450–600 μ; average 538 μ. Maximum total length to tip of pseudoparaphyses 950 μ.

On *Platynus cincticollis*. Connecticut.

This species, which is the largest known representative of the genus, being easily visible to the naked eye, is allied to *L. Nebriæ* and *L. flagellata*, resembling the latter in appearance, but easily separable from it by its great size and the details of its structure. Its trychogyne is remarkable for its unusual development, being often several times branched, and otherwise peculiar from the spiral twisting of one or more of its ultimate branches.

Laboulbenia brachiata nov. sp.

Color brown to blackish. Perithecia long-ovoid, darker towards the hyaline apex. Pseudoparaphyses blackish, or nearly hyaline; each on a small black basal disk; arising from an oblique cellular base; ten in number in a double row of five pairs; septate, the basal and sub-basal joints often inflated, especially in the outer larger pairs; dichotomously once to twice branched above the basal and sub-basal joints, the ultimate branches often very long and attenuated. Receptacle consisting of single basal and supra-basal cells, the latter slightly the longest, above which are two cells, that on the inner side the largest: above and between these two cells is a third smaller, central one, and on the inner side of this another, slightly larger cell, is separated from the perithecium by two small flat cells which form its base and are sometimes confluent. The remaining cells of the receptacle form the base from which the pseudoparaphyses arise, which is made up of five obliquely superposed cells, decreasing in size from below upwards, and separated from the pseudoparaphyses

by a row of small cells from which the latter spring directly. Spores hyaline, fusiform, septate near one extremity, surrounded by a gelatinous envelope, $60 \times 5\ \mu$. Perithecia $150–120\ \mu \times 50–60\ \mu$. Paraphyses, short $150–180\ \mu$; long $700–740\ \mu$. Total length to tip of perithecium $400–450\ \mu$. Maximum length to tip of paraphyses $950\ \mu$.

On *Patrobus longicornis*. Connecticut; (Maine, Dr. Townsend).

A remarkable form, nearly if not quite as large as the preceding species, and resembling a minute crustacean from its many projecting appendages. It is allied in the structure of its receptacle to the species figured by Peyritsch (l. c. 1873, Plate I. fig. 9), and referred by him to *L. fasciculata;* a manifest error, as a glance at the mature plant (fig. 8) must show.

Laboulbenia Rougetii Mont. et Robin.

Laboulbenia Rougetii Mont. et Robin, Hist. Nat. d. Veg. Paras., p. 622, Plate X. fig. 2.

To this species I have referred a form occurring on *Platynus*, which corresponds so closely to Robin's figures that I am inclined, for the present, to consider it merely a variety of this species. A comparison of more extensive material than I possess may show that it is distinct; yet the early stages, as well as the mature individuals, show such slight variations from the figures of *Rougetii* that it would be unsafe, at present, to refer it to any other species.

On *Platinus cincticollis*. Connecticut.

Laboulbenia fumosa nov. sp.

Color smoky brown with an olive tinge. Perithecium long-ovoid or ovoid, the apex with its hyaline pore often truncate, hardly oblique. Pseudoparaphyses arising from a base of three or four cells, itself seated on a thin black disk. Pseudoparaphyses arising from three or four inner basal cells, the walls of which are not distinct. From the outer of these basal cells extends a row of cells curving outwards and downwards (this portion is commonly broken off in specimens), black beneath, and giving rise to a variable number of straight, erect, simple, colorless branches. The inner basal cells give rise to numerous branches, erect, slender, septate, colorless, sometimes ten in number, often twice as long as the perithecium; the shorter, inner branches sometimes subclavate. Receptacle broad, tapering somewhat abruptly to its usually slender basal cell; supra-basal cell larger, broad: above it, on the inner side, two cells which separate it from the perithecium, which is itself seated on two or three small cells; above it, on the

outer side, two larger cells, which separate it from the cellular base from which the pseudoparaphyses arise; the upper of these two cells divided by a curved partition wall, which cuts off its upper inner corner. Spores fusiform, septate near one extremity, involved in mucus, 55–60 $\mu \times$ 5–5.5 μ. Perithecia 120–130 $\mu \times$ 50–75 μ. Pseudoparaphyses (longer) 75–230 μ. Length to tip of perithecium 250–300 μ. Greatest width 75–100 μ.

On *Platynus cincticollis.* Connecticut.

A small species occurring almost invariably at the apex of the elytra, rarely on the abdomen of its host. It is nearly related to *L. luxurians,* from which it is readily distinguished by its long, straight pseudoparaphyses.

Laboulbenia Harpali nov. sp.

Hyaline or very slightly straw-colored. Perithecia long-ovoid, sometimes tinged with brown, the apex (in mature specimens) black, except about the pore; longitudinal axis nearly parallel with that of the receptacle. Pseudoparaphyses hyaline, arising from a black basal disk placed opposite the middle of the perithecium; two in number, their basal cells connected; the outer irregularly once or twice dichotomously branched; the inner usually consisting of two short branches arising directly from the inner basal cell. Receptacle slender; consisting of two large stem cells (basal and supra-basal), and above them on the inner side a subspherical cell is separated from the perithecium by three very small cells. On the outer side the two cells below the pseudoparaphyses are present, the upper having the usual oblique partition in its upper inner angle. Spores fusiform, septate near one extremity, involved in mucus, 60–68 $\mu \times$ 5–5.5 μ. Length to tip of perithecium 290 μ (215–300 μ). Length of outer pseudoparaphyses 200–300 μ; of inner 100–130 μ. Perithecia 90 $\times$ 40 μ.

On *Harpalus Pennsylvanicus.* Connecticut; Maine (Kittery).

This species occurs upon the inferior surface of its host, always on the left side of the anterior, inferior face of the abdomen, sometimes extending across to the adjacent portion of the thorax. It is not uncommon, and occurs frequently in company with the succeeding species, never mixed with it, however.

Laboulbenia elegans nov. sp.

Hyaline. Perithecia ovoid; the longitudinal axis at an angle of about 40° to that of the receptacle; apex jet-black (only in mature specimens), except around the pore. Pseudoparaphyses arising from

a jet-black disk, nearly opposite the base of the perithecium; two in number, their basal cells connected. The outer basal cell giving rise to two branches; an inner, once dichotomously branched, and an outer, always simple. The inner basal cell very small, giving rise to several short branches, slightly curved, often subclavate, sometimes once branched, bearing numerous lateral or terminal antheridia. Receptacle similar to that of the preceding species, the cells merely varying in their relative proportions. Spores fusiform, septate near one extremity, involved in mucus, 40–50 $\mu \times$ 4–5 μ. Length to tip of perithecium 290 μ. Length of outer pseudoparaphyses 250–400 μ; of inner 50–75 μ. Perithecia 110–130 $\mu \times$ 50–65 μ.

On *Harpalus Pennsylvanicus*. Connecticut; Maine (Kittery).

A very pretty and distinct species, allied to the preceding; but separable at once by the position and character of its pseudoparaphyses. It is the only species observed by the writer, in which the sterile pseudoparaphysis appears to be invariable in its mode of branching. The species occurs in single tufts on the inferior surface of the thorax of its host, always on the right side.

III.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY.

XI. — ON THE CARPOLOGIC STRUCTURE AND DEVELOPMENT OF THE COLLEMACEÆ AND ALLIED GROUPS.

By W. C. Sturgis.

Presented by W. G. Farlow, April 9, 1890.

Of the many questions which, during the last half-century, have aroused more than a passing interest among mycologists, none have received more attention or excited more controversy than those relating to the nature and development of lichens. Such questions naturally present themselves under two phases, — the anatomy of the thallus, including the nature and mutual relationship of its component parts, and the origin and development of the fructification. Inasmuch as it is chiefly under the latter phase that the subject is presented in the present paper, it will be necessary to trace but briefly the course of the investigations which have led to the conclusion now generally accepted with regard to the nature of the lichen-thallus.

As is well known, the thallus of lichens is composed mainly of two elements, — a mycelial weft of hyphæ similar to ordinary fungus-hyphæ, and roundish cells of a grass-green or bluish-green color, existing either in a unicellular condition, or united into groups or into moniliform series of various types. According to the views of Fries,* published in 1831, and accepted as conclusive from that time until the year 1869, these green cells, the so-called *gonidia,* "are on the one hand nourishing organs of the thallus, and on the other hand non-sexual reproductive organs, which develop into new individuals either before, or subsequent to, their separation from the mother plant." It is hardly necessary to state that this view expresses the explanation at that time accepted of the origin and function of the gonidia of lichens, and their aggregation into the so-called "soredia."

Again as late as 1860 we find that this view of the nature of the

* Fries, Lichenographia Europæa Reformata.

gonidia is held by Schwendener, and expressed by him even more explicitly. "The green cells or gonidia," he says, "are, as is well known, lateral buds of the hyphæ, and as such are to be compared with branches. But whereas the branches, by repeated cell-division in one direction, lengthen without limit, in the development of the gonidia there occurs as a rule but one division of the primary cell to form one basal and one apical cell. The latter becomes spherical, while the former undergoes no change, and forms a longer or shorter stalk-cell." *

The continuation of Schwendener's investigations on the lichen-thallus, in 1863, indicates no change of view, and he reiterates the opinion formerly expressed by him, that "in all cases the gonidia arise as lateral outgrowths of the hyphæ, appearing therefore as spherical, green, apical cells of short, lateral, two-celled branches." † It is not until the publication, in 1868, of the concluding part of Schwendener's investigations, that the views already hinted at by De Bary with regard to the gelatinous lichens, are brought forward with much prominence, and the views held previously are seriously questioned. Speaking of the recently implied parasitic relationship between certain unicellular algæ and investing fungus-hyphæ to form a compound organism known as a lichen, Schwendener says: "Since the possibility of such a condition, and in some cases its probability, is no longer a matter of doubt, the question arises whether all lichens do not arise in the same manner." ‡

Finally, in the following year, the same observer, § breaking free from all tradition and preconceived ideas, boldly states his conclusion, based on new and more careful research, that lichens, so far from forming a group of autonomous organisms, are simply fungi parasitic upon algæ; that there exists no form of genetic connection between the two elements of the thallus; and that the compound organisms known as lichens, resulting from this peculiar condition of parasitism, are characterized by a form of fructification and development similar to that seen in many of the ascomycetous fungi. The bitter opposition which this assertion at once excited on the part of lichenologists was met by supporting arguments quite as vehement, but it is unnecessary to follow this discussion in detail here. It has been most ably

* Schwendener, Untersuchungen über den Flechtenthallus. Nägeli's Beiträge, Heft II. p. 125.

† Ibid., Heft III. p. 133.

‡ Ibid., Heft IV. p. 195.

§ Schwendener, "Die Algentypen der Flechtengonidien." See also Schwendener, "Erörterungen zur Gonidienfrage." Flora, May, 1872.

summarized in a series of papers published in the Quarterly Journal of Microscopical Science,* and to those papers the reader is referred for further information upon the subject. This summary closes with a brief account of Treub's experiments of 1873 in the culture of lichen-spores in the presence of unicellular algæ, and presents in a concise form all the evidence which conspired to establish beyond all controversy the first of Schwendener's hypotheses, that a lichen is a compound organism consisting of a fungus parasitic upon a living unicellular or filamentous alga. The grounds for this hypothesis were originally merely the remarkable similarity in outward appearance which was seen to exist between the gonidia of lichens and certain of the lower algæ, but the proof of the identity of these two similar organisms was to be found only from simple and synthetic cultures. As early as 1867, Famintzin and Barenetzky † had published the results obtained by them from the culture of the chlorophyllaceous gonidia of Physcia, Evernia, and Cladonia, which showed that from these gonidia were produced unicellular algæ identical in form and method of reproduction with Nägeli's genus Cystococcus; while from cultures made by Itzigsohn,‡ about the same time, of the gonidia of Peltigera, were produced *Glœocapsa monococca*, Kütz., and *Polycoccus punctiformis*, Kütz. Later, Woronin § confirmed these results by proving that from the zoöspores emitted by the gonidia of *Parmelia pulverulenta*, Ach., were produced algæ identical with those gonidia. In 1871 the Schwendener hypothesis received further confirmation from the experiments of Reess,|| who sowed the spores of Collema on Nostoc colonies, and produced what might easily be considered a mature Collemaceous lichen, and two years later appeared the results of Bornet's¶ experiments in more than sixty genera of lichens, from which he drew the following conclusions: — 1. Every lichen gonidium may be referred to some definite species of alga. 2. The relations of the hyphæ and gonidia are such that neither could have arisen from the other, and the theory of parasitism alone can explain them.

It was reserved however for Treub, by the synthetic culture of

* W. Archer, Quart. Jour. Micr. Sci., Vol. XIII. p. 217, and Vol. XIV. p. 115.

† Famintzin and Barenetzky, Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg, Sér. VII. Tom. XI. No. 9. Botanische Zeitung, 1867, p. 169.

‡ Itzigsohn. Bulletin de l'Academie Impériale des Sciences de St. Pétersbourg, Tom. VI. Botanische Zeitung, 1868, p. 185.

§ Woronin, Annales des Sciences Naturelles, Sér. V. Tom. XVI.

|| Reess, Monatsb. d. K. Akad. d. Wiss. zu Berlin, 1871.

¶ Bornet, "Sur les Gonidies des Lichens," Comptes Rendus, Tom. LXXIV. No. 12.

lichen-spores in the presence of Cystococcus freed from another species of lichen, and for Alfred Möller by the successful culture of lichen-spores alone in a nutritive fluid, to settle the whole matter conclusively as far as the species cultivated were concerned. Möller's cultures, the preliminary results of which were published in 1887,* included fifteen species, representing ten genera of crustaceous lichens, and established the following points: "From a lichen-spore a fully differentiated thallus can be grown, the development of which can be followed on a glass slide without the use of an opaque substratum. Gonidia never appear in such a thallus provided that the culture-method employed secures complete isolation. Experiments on the germination of lichen-spermatia led to like results. A large number of spermatia germinated like other conidia, the resulting mycelium and thalline body could not be distinguished from those developed from an ascospore of the corresponding lichen, and, like it, developed new spermogonia whose spermatia corresponded to those originally sown."

Finally, the discussion on these lines was concluded by the results, published in 1889,† of Bonnier's careful synthetic cultures, extending over a continuous period of three years, during which time, by spore cultures of a large number of heteromeric lichens in the presence of algæ procured from pure cultures of previously determined algæ, he produced a number of typical, and in some cases fruiting lichens. The reader's attention, however, must be drawn to the fact that as yet we have heard nothing from Möller on the subject of the homœomeric lichens, and that Bonnier was unsuccessful in his experiments upon Collema and Ephebe.

Meanwhile, as botanists became convinced that Schwendener's first hypothesis with regard to the parasitic nature of the lichen fungus was an indisputable fact, attention came to be directed to other kindred topics of no less interest and importance. If it had not been definitely stated, it was at least tacitly assumed by most of the earlier mycologists, that lichens were sexual in their method of reproduction, and that the spermatia were the male organs. But we have seen that from these very spermatia Möller professes to have grown fully developed thalli, without the intervention of any female organ. If this is so, it is a fact which must militate very strongly against the view that the fruit of the corresponding lichens is in any respect sexual in

* Möller, "Ueber die Cultur Flechtenbildenen Ascomyceten ohne Algen," 1887.

† Bonnier, Annales des Sciences Naturelles, Sér. VII. Tom. IX., 1889. Revue générale de Botanique, I., 1889.

its origin, for it is certainly without analogy that any form of reproductive bodies should be at one and the same time male organs, and, as stated by Möller, "conidia with slightly weakened functions," unless indeed we consider as in any way analogous the supposed reversion to a vegetative condition of the pollinodium or fertilizing cell of certain Ascomycetes. In view of the fact that these spermatia or conidia possess the function of non-sexual reproduction to by no means the normal extent, it is certainly possible that they are to be considered as degraded forms, which by disuse have lost their former sexual function, a function which we find is retained by similar organs in other lichens. This view is not without analogy. It is certainly a significant fact, that, as will be seen later, the character of the spermatia as non-sexual reproductive bodies exists only in those lichens where no form of sexual reproduction has as yet been observed with certainty, and that, in the group of lichens where sexual reproduction exists, all the knowledge that we possess regarding the spermatia points to their sexual character. There was nothing approaching any certain knowledge on this point until 1877, when Stahl published his remarkable observations on certain homœomeric and heteromeric lichens.* A reference to his paper will show that of the species examined by Stahl all but three belong to the Collemaceæ, these three exceptions being members of the angiocarpic and gymnocarpic groups of the heteromeric lichens, about which very little of a definite nature is said. On the subject of the Collemaceæ, however, Stahl is much more explicit, and his observations, depending upon careful treatment and accurate observation, seem, if true, capable of satisfactory proof. In brief they are as follows: — Stahl has observed, embedded in the gelatinous substance of the thallus, peculiar hyphæ in the form of more or less definite knots or loose spiral coils. This coiled series of richly protoplasmic cells, designated as the "ascogonium," and corresponding to what is known in certain ascomycetous fungi as "Woronin's hypha," is continued upwards in a multicellular slender thread, reaching the surface of the thallus by piercing the investing cortex, and designated by Stahl as the "trichogyne," on account of its similarity in function to the organ of that name seen in certain of the Florideæ. With the projecting tip of this organ the spermatia come in contact, and adhere to its sticky surface. Although, owing to the small size of the spermatia, protoplasmic union between them and the tip of the trichogyne has not been observed, the subsequent changes

* Stahl, "Beiträge zur Entwicklungsgeschichte der Flechten." 1877.

in both trichogyne and ascogonium point to the probability of such a union. In the trichogyne these changes are seen in the progressive thickening of the septa from the tip inwards, while the cells of the ascogonium begin to multiply in number. The vegetative hyphæ in the neighborhood then proceed to branch profusely, enveloping the ascogonic cells, and finally putting out among and between the latter a series of parallel threads, arising perpendicular to the surface, and forming the first paraphyses. The asci arise solely as ultimate branches of the ascogonic cells, and thus the two systems forming the young hymenium are from the beginning quite separate and distinct from each other.

These facts have been observed in detail only in the Collemaceæ, and Stahl explains them on the ground that the coiled ascogonium is analogous to that seen in Eurotium and Sordaria both in form and in later development, the absence of the trichogyne in these forms being due to the suppression of motile male bodies and the introduction of fertilization by a process of fusion between neighboring specialized branches. He considers the trichogyne as quite analogous to the organ of the same name in the Florideæ, and from these considerations he draws the general conclusion that all lichens are probaby provided with a form of sexual reproduction analogous in some respects to the Florideæ, and in other respects to certain ascomycetous fungi. But such a generalization is at least premature when we consider that it is only in the peculiar group of the Collemaceæ that these analogies have been traced.

With this question concerning the sexuality of lichens there has recently been connected another of almost equal importance. In all ascomycetous fungi in which some type of sexual reproduction has been certainly observed there are also found to exist two separate systems of hyphæ in the fruit, — the ascogenous system, arising from the ascogonium, and consisting of asci only, and the enveloping system, arising from the hyphæ surrounding the ascogonium, and consisting of the paraphyses and the tissue enveloping the hymenium. This fact is so marked a feature of sexual reproduction in fungi, that it seems fair to conclude that it is characteristic of such reproduction. Both these points are brought out prominently by Stahl in his investigations on the Collemaceæ, but here again the generalizations made by Stahl, and almost tacitly accepted by many later observers, are certainly not to be accounted for on grounds of analogy. The lichens, exclusive of the hymenomycetous and gasteromycetous forms, are now considered generally to belong to the great class of

the Ascomycetes. It seems pertinent, therefore, to ask why we should expect to find throughout the lichens this highly differentiated form of reproduction alone. Should we not rather, arguing from analogy, expect to find many modifications of this type, starting with that seen in the Collemaceæ which connects that group more or less definitely with the Florideæ, and including in the series some, if not all, of the modifications existing in such ascomycetous fungi as Polystigma, in which a trichogyne, while present in the form of a prolongation of a coiled ascogonium, takes no share in the formation of asci, — Pyronema, in which fertilization is effected between the swollen tips of adjacent hyphal branches by means of a tube put out from one of the tips (the male cell or antheridium) which fuses with the tip of the female cell or ascogonium, — Podosphæra, Erysiphe, Eurotium, and Ascobolus, where a coiled ascogonium is fertilized directly without the intervention of a trichogyne, by protoplasmic union between its tip and that of a specialized branch arising in its neighborhood, — and, finally, the sclerotia-forming Pezizæ and the Morchellæ, in which, with the disappearance of the carpogonium, the last traces of sexual organs are lost entirely and reproduction becomes purely a vegetative process?

The present paper embodies the results which I have obtained from the careful examination of certain species of lichens presumably most nearly related to the Collemaceæ, with the twofold object of either proving or disproving, in the lichens examined, the existence at any time of two separate systems of hyphæ in the fruit, and the occurrence of some form of sexual reproduction. I was led to a discussion of this topic by a paper recently published in "Flora,"* which deals with the same questions. The writer, after examining nine representatives of the genera Anaptychia, Ramalina, Physcia, Parmelia, Xanthoria, Placodium, Lecanora, and Lecidella, states his conclusions as follows: —

1. In all species examined, the ascus system and the enveloping system are separate and distinct from each other.

2. In all there is great similarity in the development of the apothecium to that in the Collemaceæ as observed by Stahl.

The first proposition rests on the presumed fact that there exists an ascogonium from which arise asci only, but Lindau presents no direct proof of this. The second proposition, even if we accept all Lindau's statements, states too much, since there often exists a marked discrepancy between his results and those recorded by Stahl. One point

* Lindau, "Ueber die Anlage und Entwicklung einiger Flechtenapothecien," Flora, 1888, p. 451.

observed by Stahl, and used by him very largely as a proof of sexuality, consists in the changes which take place in the trichogyne subsequent to the attachment of one or more spermatia to its tip. This point has not been observed at all by Lindau; in fact, in one or two cases he fails to observe the trichogyne at all, and merely assumes its existence from analogy. According to Lindau the trichogyne disappears entirely from older primordia in which the ascogonium has become completely enveloped by branches of the neighboring hyphæ, whereas Stahl by his figures of *Physma compactum*, Mass., shows very plainly that the changes in the trichogyne do not take place until the ascogonium is already enveloped by the hyphæ. Furthermore, Lindau confesses that he "is unable to see the bridge-like connection of which Stahl speaks between the spermatia and the trichogyne, although in this case (*Anaptychia ciliaris*) the size of the spermatia might make it easy to see any union if it existed." Stahl bases his distinction between the trichogyne and the ordinary vegetative hyphæ largely on the fact that the former never branch; on the other hand, Lindau states, in one place, that the primordia may be arrested in their development and then revert to the vegetative condition, while in others the young ascogonium bifurcates, and each branch becomes a coiled ascogonium, never reverting to the vegetative condition, the latter point being used as a proof that the ascus system is distinct from the enveloping system. There are many other points in the structure of the ascogonium and its share in apothecial formation, which differ so widely not only from Stahl's observations, but among themselves, that it seems almost incredible that they should occur in groups so nearly related otherwise as those examined by Lindau. We are at least justified in regarding the method of reproduction in the heteromeric lichens as still unsettled, and in continuing careful and systematic investigations upon their structure, until more light is thrown upon it. Taking it for granted that in the groups more nearly related in structure and habit to the Collemaceæ we should find, if anywhere, traces of a form of reproduction found in that group, and a marked separation of the ascus system from the enveloping system, I began my investigations upon members of the family Peltigerei, genus Sticta.

The method of investigation followed has been practically the same in all cases. To procure the youngest stages of apothecial development, I made a large number of sections by hand in the neighborhood of the youngest apothecia visible to the naked eye, and seldom failed to secure the desired stages. This method of making sections I have found preferable to the use of the microtome, inasmuch as the process

of embedding in paraffine seems ill adapted to the lichen-tissue. In those lichens which are invested with a tough cortex, it is wellnigh impossible to secure the requisite degree of infiltration with the reagents usually employed, and the attempt to use the microtome reveals the fact that the paraffine has penetrated very slightly, if at all, into the inner tissue of the thallus, while the gelatinous lichens are, from their very nature, liable to much distortion during the process of embedding.

To ascertain the mutual relationship existing between the asci and paraphyses, I have again had recourse to thin sections of young apothecia cut by hand, selecting for that purpose apothecia in which the young asci were just visible among the more fully developed paraphyses. By treatment of such sections with various clearing and staining reagents, and subsequently crushing them under the cover glass, the origin of both asci and paraphyses may be readily seen.

Sticta anthraspis, Ach.

The medulla of this lichen consists of a loosely interwoven layer of comparatively thick-walled, sparingly septate, hyaline hyphæ. Owing to the slight degree of complexity in the tissue, the generally regular course and the large size of these hyphæ, they may be followed separately in their course, often for a long distance, especially after treatment with alcohol to expel all air from the section, and subsequently with dilute potassic hydrate. The youngest stages of the apothecia can thus be made out with considerable accuracy. The surface of this lichen presents a peculiar pitted appearance, due to an irregular network of raised veins or ribs, which in section present the normal thalline structure. It is upon these ribs almost exclusively that the spermogonia and apothecia are borne. The former appear to the naked eye as slight elevations on the ribs, pierced in the centre by a minute dark brown pore. They arise in the upper part of the medullary layer as small spherical knots of hyphæ. As one of these knots increases in size, it becomes more and more dense, and soon reaches the outlying groups of the algal layer. Hitherto the structure of the knot has been more or less clear; now, however, it becomes very dense, and from spherical becomes ovoid, the pointed end being directed upwards. As it grows, it pushes aside the groups of algæ composing the gonidial zone, crowding them together on all sides, and frequently pushing them well back into the medullary layer. As soon as the apex reaches the thick parenchymatous cortex at one point, the cells of the latter at this point apparently increase in size, this appearance being due to the

breaking down and absorption of the membranes between adjacent cells. This lysigenetic process is continued until a pore is formed piercing the cortex, and occupying the centre of a slight elevation on the surface caused by the expansion and upward growth of the young spermogonium. Meanwhile, before the formation of the pore, the central part of the spermogonium has become hollow by absorption, and the space thus left becomes, in the mature spermogonium, almost filled with stout, branched, multicellular branches of the hyphæ forming the wall; on the joints of these — the so-called arthrosterigmata — are borne the minute spermatia in vast numbers. As yet I have been unable to secure the youngest stages in the development of the apothecium, but much may be inferred from stages already rather advanced. To the naked eye these appear as slight elevations on the ribs, closely resembling the mature spermogonia, except that they are a trifle larger, of a dark brown color, and present no trace of an orifice at the top. In section they are seen to be spherical masses of very delicate densely interwoven hyphæ about 0.3 mm. in diameter, occupying the upper part of the medullary layer, displacing the algæ immediately above them, and covered by the brown cortex. The lower half of one of these hyphal knots is permanent, and retains its dense hyphal structnre, but the upper half soon becomes disorganized, the hyphæ composing it being partially absorbed, leaving a hemispherical cavity, from the upper part of which the broken ends of the original hyphæ may be seen hanging down into the cavity. Meanwhile, as the cavity forms, the permanent tissue beneath gives rise to a series of delicate parallel threads which grow upwards into the cavity, and we thus have formed a young hymenium imposed upon a dense subhymenial layer, which owes its origin to a copious branching of ordinary medullary hyphæ. Treatment with iodine, or with chloro-iodide of zinc, has the effect of coloring both the subhymenial layer and the young paraphyses a deep yellow, darker and more pronounced than the color imparted to the ordinary hyphæ of the medulla. But no blue coloration is as yet visible in any part of the structure, nor is there any sign of a trichogyne even in this early stage, or of anything which might pass for an ascogenous system of cells in the subhymenial layer. The young hymenium increases rapidly in size by the interposition of new paraphyses as well as by the branching of those already formed, until one of two things occurs: either the increase in area of the hymenium takes place over its whole extent, until the tension upon the cortex becomes too great, and the latter is ruptured over the whole disk; or else, in cases where the apothecium arises in the gonidial layer imme-

diately under the cortex, the disk has no time to enlarge sufficiently to rupture the cortex, as seen in the first case, but the paraphyses first formed pierce it at one point, and, acting like a protruding cone, force apart its tissue. In either case, the expansion and upward growth of the hymenium soon cause it to appear on the surface of the thallus in its normal disk-like form, the elevated border or exciple being formed partially by the marginal paraphyses, but almost entirely by the cortex, which by the elongation of its cells in the direction of the course of the hyphæ, i. e. perpendicular to the surface, becomes much thickened.

The algæ composing the gonidial layer, when freed from the thallus by maceration, are seen to exhibit the bluish-green color of the Cyanophyceæ, and form almost unaltered colonies of Chroococcus, Næg. The density of the spherical mass of hyphæ forming the young apothecium excludes the algæ from it, and with the growth of the former, and the subsequent rupture of the cortex, the algæ are forced aside, so that the mature apothecium consists only of a dense subhymenial layer arising from and resting upon the normal medullary hyphæ, and giving rise above to the hymenium, the whole being surrounded by the upturned and thickened cortex. It occasionally happens that here and there an algal colony is enclosed and carried up in the lower tissue of the apothecium; but the conditions are unfavorable to its growth and multiplication, it soon dies, the contents of the cells disintegrate, and the shrunken hyaline membranes alone remain. Not until the young apothecium has burst through the cortex, and has attained a diameter of almost or quite 1 mm., do the asci appear. They can then be distinguished by treatment with iodine, and are seen to be scattered very sparingly through the whole hymenium. The iodine brings out several important features. First, the asci alone are colored, and the blue color does not extend appreciably into the subhymenial tissue. The ascogenous cells then, if they exist, do not partake of the chemical nature of the ascus membranes as exhibited by a blue coloration with iodine. Secondly, the whole subhymenial layer is colored a deeper brown than the surrounding tissue, and this coloration is homogeneous throughout the layer. The ascogenous cells then, if they exist, do not differ materially in size or in their reaction with iodine from the cells which give rise to the paraphyses. These apparent facts are borne out by further investigation. If a thin median section through a young apothecium in which asci are just beginning to appear, be treated first with alcohol to expel all trace of air, and then with dilute potassic hydrate, it becomes very transparent, and a dilute tincture of

iodine brings the asci into clear relief. By pressure upon the cover-glass the elements of the hymenium may now be separated, and if the treatment with potassic hydrate and then with tincture of iodine be repeated, and the superfluous iodine washed out with water, the asci appear colored a deep blue, and the paraphyses yellow to brown, and both may be traced to their origin. It is then seen that the subhymenial tissue consists of septate hyphæ a trifle smaller than the medullary hyphæ and much distorted by mutual pressure. Even when, as is often the case, the process of clearing has rendered the cell membranes invisible, the continuity of the deeply stained protoplasm shows that both asci and paraphyses arise from the same hyphæ. Sometimes a single ascus is seen to be surrounded by a tuft of paraphyses springing from its basal cell, and sometimes an ascus arises as a branch from the basal cell of a paraphysis. (Plate I. Figs. 1–3.) But however the two systems are related in position, they have a common origin from one and the same set of hyphæ. This fact seems to militate conclusively against the theory of sexuality, especially when taken in connection with the apparent absence of ascogonic cells, either within the thallus in the neighborhood of young apothecia, or in the tissue of the youngest apothecia themselves, and the absence, as far as I have observed, of trichogyne tips projecting above the surface.

Sticta amplissima, (Scop.) Mass.

In this species the general structure of the thallus is essentially the same as in *S. anthraspis*, the slight modifications being due to the different nature of the algæ composing the gonidial layer. Whereas in *S. anthraspis* they were united into colonies by gelatinous sheaths, here they are seen to be very small, unicellular, and bright grass-green in color, and belong therefore to the chlorophyllaceous genus Protococcus, Ag. The gonidial layer is consequently much more dense, and the medullary layer therefore more closely interwoven, and its hyphæ more irregular in their course, than was the case in *S. anthraspis*. Let us pass at once, then, to considerations regarding the formation of the fruit. It is not infrequent to find a thallus on which there is no trace of an apothecium, but which is covered with spermogonia in all stages of development visible to the naked eye. Thin sections almost anywhere in such a thallus give the youngest stages of the latter. In places there are seen, with the low power, occupying the lower part of the gonidial layer, pale oval spots. With a higher power, such a spot is resolved into a dense mass of fine branches of the medullary hyphæ, not enclosing gonidia, and therefore appearing pale

in comparison with the surrounding tissue. The cells composing these hyphæ are copiously filled with small drops of oily matter. The mass when first plainly visible measures about 68 μ in diameter. In a slightly later stage the mass has become lengthened considerably in a direction perpendicular to the surface, and is now flask-shaped, the neck — a solid cylindrical shaft of hyphæ — being almost as wide as the spherical mass below, and extending through the gonidial layer very nearly to the surface. Later stages show that this mass, the young spermogonium, now increases very rapidly in size, the centre however occupying about the same depth in the thallus. From this it follows that the mature spermogonium occupies nearly the full depth of the thallus, extending as far towards the lower as towards the upper surface. As the young spermogonium grows, the hyphæ composing what I have called the neck become more and more merged in the spherical part of the spermogonium, until at maturity the latter possesses no real neck, it is no longer flask-shaped but spherical, and its upper surface is so slightly beneath the surface of the thallus that the absorption of cell-membranes and the formation thus of a minute pore, suffices to establish a connection between the interior of the now hollow spermogonium and the outer air. As in *S. anthraspis*, the mature spermogonium is almost filled with jointed arthrosterigmata growing out from the walls, and bearing countless rather large oval spermatia.

I have said that some thalli produce spermogonia almost exclusively; as might be inferred, others are found covered with apothecia only. Near the centre they occur so plentifully that they almost hide the thalline surface; toward the margin they occur more sparingly and in younger stages, while near the extreme edge they are wanting, and a very few scattered spermogonia are found. If thin sections are made in that part of the thallus where apothecia in great numbers are just visible with the hand-lens as minute elevations of the thalline surface, we find in considerable numbers, in the lower part of the gonidial layer, small, irregularly spherical masses of hyphæ, displacing the algæ. These hyphæ are filled with small oil-drops, the masses measure from 60 to 70 μ in diameter, and, in fact, both in position in the thallus and in general appearance, they remind us of what we found to be the earliest stages of spermogonia. Closer examination, however, shows points of difference. In the first place, they occur in a thallus almost destitute of spermogonia; the masses are also more decidedly spherical, nor is there ever seen in later stages the lengthening upwards which always occurred in the young spermogonia; and, finally, the

stages in their growth may readily be followed in a series of sections closing with the mature apothecium.

Let us take one of the smallest of these masses. It measures 0.65 mm. in diameter, and of course possesses no trace of asci or paraphyses. Potassic hydrate makes the mass perfectly transparent, but the most careful search in many specimens fails to reveal anything like an ascogonium, or any cells larger or in any respect different from the vegetative hyphæ which gave rise to the mass. Furthermore, although this is presumably the youngest visible stage of the apothecium, and the disappearance of the trichogyne is always said to be the mark of a comparatively advanced stage, no coiled hypha is seen, and no vestige of a trichogyne tip is to be found projecting above the smooth, unbroken surface of the cortex. Treatment with tincture of iodine, or with a solution of iodine and potassic iodide, also fails to bring out any hint of the existence of an ascogonic system. Very often in the external part of these masses are seen, when treated with iodine, irregularly shaped bodies of a dark brown color which might easily be mistaken for the large, deeply-stained cells of an ascogonic hypha. Careful focusing, however, or if that fails, crushing of the section, shows that they are nothing more than algæ which have become separated from the gonidial layer, enclosed in the hyphæ forming the apothecial primordium, and much distorted by the pressure of these hyphæ.

The next stage in the development shows that the primordium has increased rapidly in size. It now measures from 0.18 to 0.2 mm. in diameter; but with the exception of this increased size, and a rather decided flattening of its lower part, there is no marked change. The mass is still capable of being resolved into a confused and tangled aggregation of hyphæ, but they are beginning to show a tendency to grow in a general direction more or less perpendicular to the surface. Neither ascogonium nor trichogyne has as yet appeared. One thing, however, must be borne in mind. The hyphæ composing the primordium have by this time become, by mutual pressure, rather smaller and considerably more distorted than the medullary hyphæ, and are therefore much dissimilar from them in appearance. If now a piece of an ordinary medullary hypha by any chance overlies our section in a definite position, or if, by focusing too deeply, we come upon one of such parallel hyphæ, it will present the appearance of a large-celled hypha embedded in the primordium, and might easily be mistaken for an ascogenous hypha. No mistake, however, can easily be made with regard to the presence or absence of a trichogyne, and

in none of the many sections examined by me has any trace of such an organ appeared.

We next find that the upper half of the young apothecium has disappeared, presenting the appearance of having been torn apart by the cessation of growth below, and from the upper part of the cavity thus formed are seen suspended the remnants of the hyphæ. The lower, flattened surface of the cavity is now seen to be composed of a dense layer of young paraphyses. The gonidial layer has been raised up over the young apothecium, only traces of it appearing below in the shape of a few separate algæ, or small groups of them, which have been embedded in the lower part of the young apothecium and remain there. The first evidence of the coming exposure of the hymenium, is seen in the loosening of a broad, wedge-shaped portion of the algal layer and the cortex immediately above the young hymenium, as though by the expansion of the latter it were to be thrown off bodily. The later development is like that described in the case of *S. anthraspis*. Before the cortex is ruptured, and the hymenium exposed, the asci begin to appear, at first sparsely throughout the hymenium, but soon in greater numbers; the tissue covering the disk is thrown off, and the hymenium, surrounded by a thick, thalline exciple, appears on the surface. To determine the origin of asci and paraphyses the same method of treatment may be employed as before; and here again the asci alone are colored blue, the coloration not extending into the hymenium. No more than in the case of *S. anthraspis* is it possible to find two separate systems of hyphæ in the subhymenial tissue. The figures (Plate I. Figs. 4–6) show a variety of forms by which the relation between the asci and paraphyses is established.

NEPHROMA TOMENTOSUM, (Hoffm.) Krb.

The genus Nephroma, as already pointed out by Schwendener * and also by Tulasne,† forms a connecting link between the genera Sticta and Peltigera. To quote from the author first named, "Whereas the peltate, borderless apothecia emphasize the affinity of this genus (Nephroma) to Peltigera and Solorina, the anatomical structure of the thallus presents such a perfect agreement with that of Sticta, that it is impossible to find a single characteristic which cannot also be found in one or another species of the circle of Sticta forms." ‡

* Schwendener, Nägeli's Beiträge, Heft III. p. 166.

† Tulasne, Mém. Lich., pp. 20 and 145.

‡ Schwendener, *loc. cit.*, p. 173.

In the thalline structure of the species before us, we find so marked a resemblance to that of *Sticta anthraspis*, that we may pass at once to a brief consideration of the origin and growth of the apothecium. As is well known, the large, peltate apothecia occupy rather sparingly the lower surface of the extended lobes, and it is a matter of some difficulty to obtain the earliest stages in the development of the fruit. By making careful longitudinal sections, however, through the tips of the thallus lobes, I was enabled to see more or less plainly the origin, and to trace the later development, of the apothecia. The first sign of the coming apothecium is the appearance of a small spherical knot of hyphæ arising from the medullary hyphæ, and occupying a position immediately below the algal layer, which, at the margin of the thallus, is very thin and composed of only scattered colonies. The primordium never occupies the exact tip of the margin in section, but inclines more or less toward the lower surface, sometimes, indeed, arising from the medullary layer beneath the lower cortex and at some distance from the margin. The few algal colonies which do occur between the primordium and the lower surface of the thallus are pushed aside by the growth of the former, which then remains covered only by the cortex. Before the cortex is disintegrated or ruptured, the young paraphyses arise as perpendicular branches of the knot of hyphæ. No part of the knot, or of the paraphyses arising from it, is colored blue by iodine, but the whole gives homogeneously the ordinary protoplasmic reaction. The growth of the young hymenium by the interposition of new paraphyses is equally rapid over the whole area, so that the cortex covering it is stretched more and more, and finally ruptured simultaneously over the whole disk. The hymenium then increases even more rapidly than before, relieved of the tension of the cortex, and if it does not already occupy the lower surface of the thallus, the addition of paraphyses is more in that direction, and by the time the young apothecium is distinctly visible to the naked eye, it is seen to occupy entirely that position. Often four or five young apothecia arise in such close proximity to one another, that, in the ordinary course of growth, the intervening tissue is broken down, and one large apothecium results.

A section of the young apothecium exhibits a margin of extremely simple structure, if indeed it can be called a margin at all. By reason of the pressure exerted by the growing hymenium upon the investing cortex, the cells of the latter are lengthened considerably in the direction of hyphal growth, i. e. perpendicular to the surface; those hyphæ of the cortex which are in direct contact with the paraphyses become distinguishable from them only by their greater diameter, and the

margin here equals in thickness the height of the paraphyses. They retain more and more their original dimensions as they recede from the hymenium, until they are found to present entirely their normal appearance as cortical hyphæ. Until the apothecium is nearly half the size which it attains at maturity, the asci remain invisible, being enveloped and covered by the semi-gelatinous membranes of the paraphyses; but the same treatment which was made use of before serves here also to bring the asci into relief. I have found it advisable, however, in all cases where the membranes of the paraphyses are of so gelatinous a character as in this species, to avoid the use of any alcoholic reagent, inasmuch as the alcohol induces a contraction and hardening of the tissue which effectually prevent subsequent maceration. If it is found necessary to stain the asci, an aqueous solution of iodine and potassic iodide may be used. Subsequent maceration shows that the subhymenial layer consists of branches of the medullary hyphæ so densely woven together that a pseudo-parenchymatous tissue results, the cells of which, although in places they still retain a linear arrangement, have as a rule become swollen and distorted by mutual pressure, and are rather larger and more nearly isodiametric than the original hyphal cells which they represent. From this tissue both asci and paraphyses arise indiscriminately, the paraphyses first, and later the asci, pushing up between them. There is no visible differentiation of the subhymenial tissue into ascogenous and paraphyses-bearing hyphæ; both arise from one and the same tissue of medullary hyphæ, modified, it is true, but not into two dissimilar systems. (Plate I. Figs. 9–11.)

Peltigera, (Willd., Hoffm.) Fée.

Of the genus Peltigera I have examined but one species, *P. polydactyla*, (Neck.) Hoffm., and very little need be said with regard to it, owing to the similarity existing between it and the other genera previously studied. The thalline structure resembles very closely that of *S. amplissima*, but approaches more nearly still perhaps that of *N. tomentosum*, the only important anatomical difference being the absence of the cortex on the lower surface. Peltigera differs carpologically from Nephroma only in the fact that whereas in the latter, as we have seen, the apothecial primordium arises near the lower algal zone, and when mature occupies the lower surface of the thallus lobe, the primordium in Peltigera arises just below the upper algal zone, and, its growth being exclusively toward the upper surface, the mature apothecium occupies that surface. I have been unable in Peltigera, as in Nephroma, to find any trace of a carpogonic apparatus. The origin

and development of the apothecium seem to be purely vegetative processes, nor, as far as I have observed, is there any distinction, at any stage in the development, between the ascogenous and the enveloping systems of hyphæ. Owing to the gelatinous quality of the membranes of the paraphyses, and the frequent fusion of their tips, it is a matter of much difficulty to separate the elements of the hymenium and trace them to their origin. This may be done, however, as in Nephroma, by careful crushing, after treatment with potassic hydrate and then with an aqueous solution of iodine and potassic iodide. The blue coloration of the asci is as permanent as with the tincture of iodine. The coloration of the protoplasm, however, is readily washed out by the subsequent treatment with water, though this will be found to be no particular disadvantage. (Plate I. Figs. 7, 8.)

Thus far we have considered types of genera which present on the whole the structural characteristics of the heteromeric, foliaceous lichens. But we have already seen tendencies toward another type. In *Nephroma tomentosum* we have seen that the algæ forming the host are no longer of the grass-green, unicellular type, but are bluish-green cells united into colonies, and belonging evidently to the phycochromaceous genus Glœocapsa, Näg., and the same is true of many species of the genus Peltigera. In fact, the family to which this latter genus belongs presents in a very marked degree this transitional character with respect to the gonidia. Three of the five genera included in it by Tuckerman are characterized by bluish-green algæ in one group of species and grass-green algæ in another group; another genus possesses both types of algæ in one and the same species, while the fifth genus is parasitic on bluish-green algæ alone. Coming to the family Pannariei, however, we find this transitional feature even more strongly marked, one only of the four genera being in part parasitic on grass-green algæ. Furthermore, we shall see that in this genus we begin to lose sight of the Chroococcus and Glœocapsa types of algæ, and find a marked approach toward the homœomeric lichens in the occurrence of a filamentous type of alga. Finally, in the loss of the lower cortex in the genus Peltigera, we must recognize an added link in the chain of evidence connecting the heteromeric with the homœomeric lichens.

PANNARIEI.

In this family, presenting as it does, so many structural characteristics which are emphasized in the true gelatinous lichens, we might fairly expect to find traces at least of the type of sexual reproduction presumably characteristic of the Collemaceous lichens.

Heppia, Näg.

The first member of this great family which I have studied accurately is the genus Heppia, represented in North America by two species, *H. Despreauxii*, (Mont.) Tuck. [*H. urceolata*, (Näg.) Hepp, *H. adglutinata*, (Krmph.) Mass.], and *H. polyspora*, Tuck. The former presents many characteristics which adapt it peculiarly to anatomical study. In thin sections of the small thallus lobes we are at once struck by the fact that the fungus hyphæ, instead of pursuing a general direction parallel to the substratum, and forming a more or less closely interwoven tissue, occupy a position perpendicular to the substratum. This peculiarity is accentuated, and doubtless induced, by the position of the gonidial algæ. Instead of being scattered singly or in groups, they present a more or less pronounced linear arrangement parallel with the hyphæ. The hyphæ themselves are extraordinarily large, measuring near the substratum 4 μ in diameter, and increasing rapidly in size until at the upper surface the individual cells measure 18.8 $\mu \times 11.3 \mu$. The cell walls are very thin, and the hyphæ lie closely packed together, so that the hyphal character of the thallus is lost except near the substratum, where the separate hyphæ are smaller and the texture looser. The cortex, when present at all, shows a marked change from that seen in the preceding forms, being reduced on the lower surface to a single layer of rather large thick-walled cells of a brownish color, while the upper surface is destitute of a cortex, unless we accept as our idea of a true cortex Schwendener's statement,* that "only a few layers of cells (sometimes only one) are destitute of gonidia, and may therefore be regarded as a cortex." The superficial cells, it is true, are covered by a delicate, hyaline, structureless layer, and the superficial cell wall is slightly thickened and colored brownish, but the differentiation of the cells composing this layer from the cells below is hardly sufficient to warrant our regarding the former as a true cortex. The gonidial and medullary layers are as little to be distinguished as distinct zones, inasmuch as the algæ occupy nearly

* Schwendener, *loc. cit.*, p. 178.

the full depth of the thallus; in fact, the whole character of the thallus would lead us to regard Heppia as one of the terminal members of a transitional series of forms connecting the heteromeric and homœomeric groups.*

I have before referred to certain peculiarities exhibited by the algæ of this lichen. Their peculiar arrangement, brought out most plainly with the low power, seems to indicate that we have to do with an originally filamentous alga, the elements of which have become partially displaced and altered in form by the encroaching hyphæ. This view is confirmed when, on crushing a section of the thallus, we are able to separate short chains consisting of four or five large, bluish-green cells. The analogy between these chains or filaments and the filamentous alga Scytonema, Ag., was first pointed out by Bornet,† and an examination of the species before us leaves no doubt of the truth of the analogy, although I have not as yet found the filaments still invested by the gelatinous sheath characteristic of Scytonema. Such filaments, however, do occur in all cases, upon the substratum under and around the thallus-lobes.

The origin and development of both spermogonia and apothecia differ only in minor particulars from what has already been observed and described in other lichens. The former are extremely small, a fact which, taken in connection with their rather infrequent occurrence and inconspicuous character, might cause them to be overlooked. Careful sections, however, near the edges of the thallus-lobes bring to light, generally just below the median line of the section, small hyaline areas in the midst of the surrounding algæ which on further examination are resolved into ovoid masses of delicate interwoven hyphæ. The later stages of development may be readily followed, and, being similar to those already described, are too familiar to need repetition here. By the time the apex of the young spermogonium has reached the surface, the central portion of the mass has been absorbed, and a pore is formed by a schizogenetic process, the hyphæ forming the short neck separating in the centre and forcing apart the parallel hyphæ surrounding them. The primordia of the apothecia resemble very closely the young spermogonia, except in size. When still distinguishable in the thalline tissue as only a dense, spherical mass of delicate, hyphal branches, they are already more than twice the size of the spermogonia of the corresponding stage of development. At this early

* Cf. Koerber, Parerga Lich., p. 26.

† Bornet, Ann. des Sci. Nat., Sér. V., Vol. XVII.

stage there is no visible sign of ascogonium or trichogyne, or indeed of anything which might indicate in the least degree any sexual origin of the apothecium. The apothecium originates rather above than below the median line of the section, so that there exist beneath it considerable numbers of gonidia. As the apothecium grows, it encroaches more and more, not only on the overlying tissue, but also on that below, the result being that the algæ occupying the latter are pressed together downward, and finally form a dense compact layer beneath the apothecium. If we accept the view that the presence of the algæ may induce a more vigorous growth in the hyphæ, this fact of the accumulation of the algæ may account for the origin of the cortex which is always found covering the lower surface immediately beneath the mature apothecium. There is one point in the development of the apothecium to which attention must be drawn. The young paraphyses, arising very early as perpendicular branches of the upper part of the primordium, attain their full length before the cortex is ruptured. The subsequent growth of the hymenium is entirely in area, and by this means the cortex is soon ruptured; but whereas in the other cases examined the later growth of the paraphyses and subhymenial tissue raises the hymenium considerably above the surface, in Heppia the upward growth has ceased by the time the cortex is ruptured, and the apothecium remains sunk in the thallus and separated from the thalline tissue only by a thin layer, one or two cells in thickness, formed of the compressed thalline hyphæ. Not until the hymenium is nearly or quite exposed do the asci appear, rising from the dense subhymenial tissue and pushing up between the paraphyses. Meanwhile the treatment followed in other cases fails to show the presence of any differentiated cells in the subhymenial layer. I have been unable to see any trace of a trichogyne, and maceration after treatment with potassic hydrate shows a relation existing between the asci and paraphyses identical with that seen in the other genera studied. (Plate IV. Figs. 23–25.)

PANNARIA MOLYBDEA, (Pers.) Tuck.

In this lichen we find a very peculiar thalline structure. The lower part of the thallus is formed of a dense layer of hyphæ running parallel with the substratum, or more or less obliquely to it. This layer is continuous around the edge of the thallus, and forms upon the upper surface a layer which is thinner and more strikingly parenchymatous than the layer forming the lower surface. There is thus left a space between these two parallel layers which is filled by a much looser tissue of hyphæ arising from the lower layer and growing upwards to

become merged in the upper layer. The position of the algæ is in conformity with this peculiar structure. Scattered very sparsely through the dense lower layer, and corresponding in their course to that of the hyphæ in which they are embedded, are seen long filaments of bluish-green cells. In the loose tissue forming the central part of the thallus these filaments are shorter, and the cells composing them are considerably larger, than those of the scattered filaments below, (since the latter are decidedly compressed by the density of the surrounding tissue,) and their general position is perpendicular to the surface. This structure of the thallus must be fully understood in order to enable us rightly to interpret the stages in the development of the fruit. The spermogonia arise in the lower part of the loose central tissue, and present in respect to their origin and development no peculiarities worthy of notice. The origin of the apothecia is more peculiar, and more difficult to follow. The first step takes place in the form of an active branching, in a purely vegetative manner, of the hyphæ composing the upper part of the dense layer of parallel hyphæ already noted as bounding the thallus on its lower surface. This tendency to increased activity in growth, starting at one point, is transmitted to the loose tissue above, in which the algæ are embedded. These algæ (seen by crushing the section to be filaments of Scytonema even less altered than in Heppia) are, with few exceptions, pushed aside, and the uppermost layer of parallel hyphæ begins to take part in this active growth. But whereas in the deeper layers the area of growth is equally bounded on all sides by the thalline hyphæ, and has therefore no tendency to increase in one direction more than in another, the hyphæ forming the upper layers, when stimulated by the growth below, can grow freely upwards. Such a growth takes place, and the iso-diametric cells composing this layer begin to increase in length in a direction perpendicular to the surface. Thus these cells which here take the place of a true cortex are themselves transformed into a layer of upward-growing hyphæ, and, as we shall see, are to be considered as forming a subhymenial layer. (Plate II. Fig. 12.) We find accordingly the appearance of an inverted cone, the base composed of these metamorphosed superficial cells rising to a height above the normal surface of about 0.05 mm., the apex resting upon the dense layer forming the lower portion of the thallus. This condition of things is quite different from that seen before, where an existing cortex was ruptured by a hymenial disk arising beneath it. The parallel hyphæ forming the subhymenial layer upon the surface now begin to branch copiously, the branches arising parallel with the hyphæ

themselves, thus increasing very rapidly the area of the disk. But already this disk is elevated above the surface, and, being free to expand on all sides, spreads out in a fan-like manner, its edges encroaching more and more upon the thalline surface around it. Finally the hyphæ forming the central area of the disk give rise, from their tips, to elongated cells, which may at once grow into either asci or paraphyses, or may again bifurcate and produce the asci and paraphyses as a second order of branches. (Plate II. Figs. 13–16.)

The tips of the hyphæ, which, by the spreading out of the margin of the apothecium over the thallus, have come to be directed obliquely, or even perpendicularly, to the surface, elongate, and though I have been unable to see with certainty any definite anastomosis between these tips and the cells composing the thalline surface, they undoubtedly serve to attach the lower surface of the apothecium to the surface of the thallus. The extremely gelatinous character of the mature apothecium may be seen from the fact that when wet it becomes almost transparent, so that small foreign bodies on the surface of the thallus may be seen with a hand-lens through the tissue of the overspreading apothecium. This gelatinous quality renders it a matter of extreme difficulty to separate, sufficiently for exact study, the elements of the hymenium. With care and patience, however, it may be done. The asci are colored blue with any preparation of iodine, but no other part of the apothecium is so affected, nor at any stage in its growth, as far as my observation goes, does treatment with iodine bring to light any differentiated cells which might be mistaken for ascogonium, trichogyne, or ascogenous cells. The whole process of growth seems to be a purely vegetative one.

Pannaria rubiginosa, (Thunb.) Delis.

In the group of Pannaria species represented by *P. rubiginosa* we have a still nearer approach to the Collemaceous type. The anatomical structure of the thallus, while on the one hand, by reason of the presence of a thick cortex investing the upper surface and the absence of cortex on the lower surface, it seems to revert to the Peltigera type, seems on the other hand, from the nature of the algæ and the character impressed upon the thallus as a whole by that nature, to be differentiated widely from all preceding types. The algæ occupy nearly the full depth of the thallus, and at first sight present the appearance of irregular groups of small bluish-green cells embedded in spherical masses of jelly. By crushing a thin section, however, the cells composing these groups are seen to be arranged, not in straight filaments as in Heppia and *Pannaria molybdea*, but in curved chains

of small spherical cells provided here and there with definite heterocysts. Each of these chains is embedded in a definite, more or less spherical mass of jelly, and by any one familiar with the types of the lower algæ they are recognized as unaltered Nostoc colonies.

With the exception, then, of the fact that the hyphal nature of the thallus still preponderates slightly over that induced by the gelatinous sheaths of the Nostoc colonies, this lichen presents us with a structure identical with that seen in Leptogium.

It is a matter of very little difficulty to find the earliest stages of the reproductive organs, both spermogonia and apothecia. They are mostly limited to separate thalli, and are densely crowded, the apothecia particularly, occupying the centre of the lobe in large numbers, the edges being comparatively free from them. If then a series of sections be made progressively from the edge towards the centre, the different developmental stages can be clearly traced. It occasionally happens that near the edge of a thallus lobe, otherwise provided with apothecia only, there occur a very few spermogonia, and in such cases a comparison of the early stages of the two organs lying side by side in the same section is very instructive. Nothing further need be added here to the course of spermogonial development already described.

The apothecial primordia differ considerably from the youngest spermogonia. In size they are rather larger, in shape they are much more spherical, and in position they are more deeply sunk in the thallus, so that very few algal colonies occur below them. The structure and origin of the small, spherical masses of interwoven hyphæ forming the primordia are easily made out, and although it seemed highly probable, from the close relationship evidently existing between this lichen and the Collemaceæ, that here would be found some form of sexual reproduction analogous to that described by Stahl in Collema, I was unable to find any trace of such a condition. Before the simple character of the young apothecium has begun to give place to the more complex condition seen later, the thalline elements above it begin to disorganize. What this result is due to it is impossible to state. The growth of the primordium undoubtedly exerts a tension on the overlying tissue, but the disintegration seems rather to be caused primarily by the death of the protoplasmic contents of the cells, and the absorption of the membranes, in a manner similar to that which produces the central cavity in the young spermogonium. But from whatever cause, by the time the first paraphyses have arisen from the upper part of the primordium, the overlying tissue has disappeared, and the young hymenium, though still deeply sunken in the

thallus, is free above. The growth now becomes more rapid, the disk enlarges, and, at the same time growing upwards, rolls back the thalline elements, so that by the time the disk appears on the surface it is surrounded by a large thalline exciple. The treatment adopted in other cases shows that here also both asci and paraphyses arise from a common system of hyphæ forming the thin hypothecium. (Plate III. Figs. 20, 21.) It often happens that the disk enlarges very much after reaching the surface, and that the exciple is thereby rolled back upon the thallus. Thus the cortex enveloping the apothecium is bent back upon the cortex of the thalline surface, and the former, as in *P. molybdea*, puts out hair-like processes which soon form an intricate hyphal layer. (Plate III. Fig. 18.) There are thus formed beneath the mature apothecium, except at its centre, two layers of cortex separated from each other by a loose weft of hyphæ.

COLLEMEI.

In approaching the truly homœomeric groups of lichens, we realize at once that we are now on debatable ground, for it is this group which formed the basis for the theory of lichen-sexuality, the one group, so far, in which the conclusions reached by Stahl and his followers seem plausible. In the subfamily Eucollemei, as understood by Tuckerman,* we find five genera, of which the last, the peculiar genus Hydrothyria, Russell, will first occupy our attention. I take up the consideration of this lichen now, instead of later, because I cannot but regard the synoptical position which it at present holds as by no means a settled one. Writing upon this point Tuckerman himself says: "In this type (Hydrothyria), remarkable alike in its characters and its habitat, Collema, Ach., which we found to reach its extreme of development in the Leptogia of more recent authors, may be said now to revert evidently towards Pannaria, or even Peltigera." † Instead, however, of regarding this type as a reversion to a preceding type, it seems more fitting, for the present at least, to consider this form as following directly upon the Peltigerei and Pannariei, which in many points it most closely resembles, and as forming an additional link between the homœomeric and heteromeric forms, while inclining decidedly toward the latter. The habit of *Hydrothyria venosa*, Russ., the only known representative of the genus, although in some measure like that of Leptogium, seems to approach much more nearly that of

* Tuckerman, Synopsis of North American Lichens, p. 5.

† Tuckerman, Genera Lichenum, p. 102.

Nephroma. It is however more decidedly erect and foliaceous than that lichen, the broad, undulate, fan-like lobes being frequently 3 cm. wide, and contracted below into a stalk which serves to attach the plant to the substratum. Frequently several such fronds are found growing together in a dense tuft, the expanded portions floating freely in the water, and often they form a dense growth covering the rocky bottom of the brook in which they occur over an area several feet in extent. Although at times, when a frond is pressed down upon the rocky substratum, it puts out from its lower surface a growth of rhizoids by which it becomes attached to the rock, in its normal condition, as far as my observation goes, the frond floats erect in the water, attached only by the short stalk-like contraction of the base referred to above. At the point where this stalk expands into the frond it gives rise to a number of veins which, in a manner analogous to that seen in Peltigera, spread out over one surface of the thallus, seldom anastomosing, however, except where they reach the free edge of the thallus-lobe or frond.

It will be seen, then, that Hydrothyria, while resembling Leptogium superficially in its rich olive-brown color, presents on closer examination points, even of habit, which are in no degree analogous to that genus. This fact is emphasized when we come to study the thallus in detail.

In considering the structure of the thallus, I will dwell at greater length upon those points which are indicative of the synoptical position of this lichen, — the general character of the thallus, the presence or absence of a cortex, and the nature of the algæ forming the host. If we examine a radial section of the thallus, we find that its structure near the centre differs materially from that near the edge. In the former case the hyphæ are very large ($5.6\ \mu$ to $7.3\ \mu$ in diameter), and in the lower part of the thallus maintain a comparatively regular course parallel to the surface of the thallus. Owing to their large size and the comparative regularity of their course, the individual hyphæ may often be traced to a considerable distance, the interweaving and branching being not such as to cause much complexity of structure. In fact, the structure of this layer is much like that seen in the lower part of the thallus of *Pannaria molybdea.* On the lower surface this layer is bounded by a cortex consisting of a single row of cells which are differentiated from the cells immediately above them by their thicker and slightly brownish walls. This simple structure of the cortex recalls a like condition seen in Nephroma. The central part of the thallus is occupied by the wide algal zone, composed of dense aggregations of small bluish-green cells, among which the hyphæ run in inextricable confusion. So irregular is their course as

they traverse the algal zone, that the section has almost the appearance of a parenchymatous tissue, in the midst of which lie the groups of gonidia with no apparent regularity. On the upper surface we find the thallus bounded by a simple cortex developed from the medullary hyphæ, and in no way distinguishable from that which covers the other surface. (Plate V. Fig. 31.) It is almost impossible, so dense is the tissue, to determine from sections what is the nature of the gonidia, or even whether they are unicellular or filamentous. On crushing the section the algæ are freed with some difficulty from the investing hyphæ, and appear unicellular. Their shape, however, is not at all that of the ordinary unicellular gonidia. They are extremely irregular in outline, and generally present one or more flattened surfaces, as though they had originally been members of a moniliform series. By exercising great care I was finally able to separate a few groups of these cells without their becoming entirely disintegrated, and they then appeared as filaments composed of three to seven cells very similar in size and arrangement to the gonidia of *Pannaria molybdea*, though much more distorted by reason of the greater density of the investing tissue. (Plate V. Fig. 33.) They are undoubtedly of the Scytonema type, a fact which, if the nature of the host is to be considered of any importance in determining the systematic position of a genus, would bring Hydrothyria into relation with Pannaria rather than with Leptogium.

Although the algæ are more or less restricted to a certain zone of the thallus, this zone is so wide that the thallus cannot certainly be called heteromeric, but seems to approach much more nearly the partially homœomeric character of the Pannaria thallus, while, on the other hand, it is not truly homœomeric if we consider Leptogium as a type of such a thallus, nor does it partake of the gelatinous character of the Collema thallus. Toward the edge of the thallus, even the slight regularity seen in the arrangement of the hyphæ in the older portions gradually disappears, and the margin of the thallus presents in section only a very intricate texture of delicate hyphæ, occupied throughout by the algæ. The veins present essentially the same structure throughout. The hyphæ composing them arise as branches of the medullary hyphæ, and, pursuing a regular radial course, soon become united into firm bundles. The individual hyphæ become considerably increased in size near the point where the bundle arises from the medulla of the contracted base of the thallus frond; thus the bundle itself encroaches upon the thalline elements lying between it and the surface, and the latter becomes elevated in the form of a ridge or vein. (Plate V. Fig. 31.) As we approach the edge, the bundles of hyphæ

become smaller, and the veins therefore are less prominent, until at the extreme edge the ramifications are very delicate and anastomose at various points.

The structure of the thallus, then, though less gelatinous in its quality than that of *Pannaria rubiginosa*, would bring Hydrothyria into more or less close relationship with that genus. The presence of a well-defined cortex investing both surfaces of the thallus would give to Hydrothyria a position in our system farther removed from Leptogium and Collema than is Peltigera, — a position more nearly approaching that occupied by Nephroma, — while the character of the gonidia, on the other hand, would bring it into relationship with Pannaria and Heppia. While, then, Hydrothyria is to be considered in no sense as Collemaceous in its type, it becomes a matter of great difficulty to say exactly where it should be placed. It would seem fair to consider it as a member of the Pannaria type serving to connect that genus with the Peltigerei.

The development of the fruit is not an easy matter to follow. Spermogonia have not as yet been known to occur, nor have I been able to discover any sign of such organs, though I have examined material collected at different seasons of the year and in many localities. Material collected near New Haven, Connecticut, in June, 1889, has proved the best for the study of apothecial development. On these specimens the fully developed fruit is rarely seen in quantity, nor in dried specimens is it easy to detect the young stages. In fresh, moist material, however, the young apothecia may be seen with a hand-lens occupying in considerable numbers the extreme edges of the expanded thallus lobes. The marginal position of the fruit is a rule to which I have as yet seen no undoubted exceptions. It is true that a mature apothecium is occasionally found at some distance from the margin, but by examining younger stages it will be readily seen that these have arisen at the bottom of a sinus such as frequently extends deeply into a thallus lobe, and that by the marginal growth of the thallus around and beyond the young apothecium, the latter comes to occupy a position considerably removed from the margin. The young apothecia usually arise at a point on the margin of the thallus where the fine ramifications of the veins meet and anastomose, and if sections be made at such points it is a mere matter of time and patience to find the youngest stages. These are at first observable only as a slight change in the ordinary thalline structure of the extreme margin. The hyphæ are seen to be even more densely interwoven than normally, the usually very thin margin has thereby become slightly swollen, and

the cortical cells, as well as those immediately beneath them, are seen to be colored brownish. These initial appearances would mean but little did they not later become more emphasized, and more evidently associated with apothecial development. The tip swells more noticeably, owing to the active branching and interweaving of the hyphæ, and becomes club-shaped or even subspherical in section, the cortex becomes in many cases dark brown in color, and the delicate branches composing the upper part of the complex mass of hyphæ which causes the swelling of the tip, exhibit at the central point a slight tendency toward a regular arrangement perpendicular to the surface. As yet there has appeared no definite hyphal coil in any part of the tissue under examination, nor have I been able to discover, either in the tissue or on the surface, any appearance of a trichogyne. The tendency toward a regular arrangement in the upper part of the primordial mass of hyphæ soon becomes more marked, and there now exists, just below the surface, a layer of short parallel threads, the young hymenium, springing from the dense tissue of the primordium, and still in genetic connection with the tissue above. The tip in section, owing to the expansion in area of the young hymenium, becomes less spherical and flatter, and the brown coloration, considerably less marked than before, is now limited to the cortex immediately above the young hymenium. The paraphyses attain a length of 25 μ to 30 μ, and then their rate of growth becomes much less rapid. The same partial cessation of growth does not however take place in the surrounding and overlying tissue, and the latter, forced upwards, becomes torn away from the paraphyses and forms above the disk an arched cavity.

At this, or at a slightly earlier stage, there are to be seen in the hypothecium certain cells, the origin and object of which I am at a loss at present to explain. They are differentiated from the surrounding cells by their greater size, more rounded shape, and oily or granular contents. Their arrangement, furthermore, seldom exhibits any degree of regularity. The tissue overlying the disk gradually begins to show signs of approaching dissolution. The brown color of the rind spreads to the tissue beneath, and the whole mass covering the young hymenium becomes yellow or brown. The later development is quite normal. The expansion of the disk ruptures the rind in a stellate manner, and as soon as it appears upon the surface the hymenium increases with such rapidity that the thallus is bent back upon itself.

The formation of an exciple is extremely simple. As soon as the cortex is ruptured, the paraphyses again increase rapidly in length, until their tips are level with the surface, and the cortex, instead of being

rolled back, gradually disappears over the whole disk. The exciple of the mature apothecium then is not elevated above the hymenium, and the apothecium itself resembles in cross-section a shallow cup, the sides of which are elevated above the thalline surface, but not above the hymenium. Carpologically therefore, as well as structurally, Hydrothyria presents a marked affinity to Pannaria. It not infrequently happens that a double apothecium is formed. Both surfaces of the thallus being often, from their upright position in the water, equally exposed to external influences, the tendencies are only slightly, if at all, in favor of apothecial development on one surface rather than on the other, so that the primordium may give rise to a hymenium on both surfaces, and we have as the result two apothecia on opposite surfaces of the thallus. (Plate V. Fig. 32.) This equalization of tendencies pervades the whole thallus, there being nothing in sections to distinguish accurately one surface from the other, except the venation and the occasional feeble and scanty growth of short, hair-like processes where one surface by chance comes in contact with the substratum.

By employing the same treatment as heretofore, the asci and paraphyses may be traced to their origin with comparative ease, owing to the non-gelatinous quality of the hymenium. (Plate IV. Figs. 26, 27.) Treatment with iodine stains the asci alone blue, and the presence of larger cells in the hypothecium is no longer visible. This disappearance of cells previously seen to exist may be explained in one of two ways. The primordium, and therefore the hypothecium, as has been shown, are formed by a copious branching of the medullary hyphæ, these branches being much finer than the hyphæ from which they arise. Now it is almost to be expected that before the dense tissue is fully formed, and while the branches are still arising, it might easily happen that portions of the medullary hyphæ would become enclosed in this forming tissue. They would remain visible until completely overgrown, when they would become compressed and distorted to such a degree as to be no longer recognizable. If however we choose to consider them as analogous to the Woronin's hypha of certain Ascomyceteæ, notwithstanding their lack of any regular arrangement, we must believe that we have to do here with a form of reproduction analogous to that seen in Xylaria, and said to be characterized by the disorganization and disappearance of the Woronin's hypha and the absence of a trichogyne. Following out this analogy, we are led to the conclusion reached by De Bary in the case of Xylaria, that " the ascogenous cells and hyphæ do not spring from a distinct ascogonium, but, like the paraphyses, from parts of the primordium, while the

ascogonium, unmistakably present as Woronin's hypha, perishes without taking part morphologically in the formation of asci." This would account for the presence of the larger cells in the primordial tissue, and their absence later, but I must confess that such an explanation seems to me decidedly strained, though perhaps no more so than in the case of Xylaria already mentioned.

The absence of a trichogyne in Hydrothyria is to my mind as certain as in the other lichens studied, although in all cases the statement rests upon a purely negative proof. If we crush thin sections of an apothecium in which the asci are still young, (the same treatment being employed as formerly,) the elements of the hymenium may be separated easily. The paraphyses then appear as delicate, filamentous threads, which are either simple or copiously branched, and frequently exhibit a form of anastomosis by means of a bridge-like connection. (Plate IV. Figs. 28–30.) Both asci and paraphyses arise from the same vegetative cells of the subhymenial layer, and exhibit the same mutual relationship as in the other forms studied. (Plate IV. Figs. 26, 27.)

In conclusion, then, Hydrothyria can be regarded in no sense as a transitional form between the true foliaceous lichens of the Pannaria type and the gelatinous Collemaceæ. The presence of a cortex investing both surfaces of the thallus, the non-gelatinous character of the thalline tissue, and the Scytonemoid gonidia, are facts which taken together would give to the genus an anomalous position in the neighborhood of Peltigera and Pannaria. If such a transitional form does occur, it must rather be looked for in the genera Pannaria and Physma, where the Scytonema type of gonidia has given place to the Nostoc type, and where the dense but large-celled hyphal tissue of Heppia, in which the hyphæ give the character to the thallus, has, by the necessity arising from a decidedly gelatinous host, become modified, so that now the gelatinous membranes of the algæ preponderate, and take an equal or greater share with the hyphæ in impressing a definite character upon the thalline structure. Furthermore, as already noted by Tuckerman,* no one can examine the two species of Physma without being at once struck by the remarkable similarity in thalline structure, on the one hand, between *Physma luridum* and *Pannaria rubiginosa*, and, on the other, between *Physma byrsæum*, (Mass.) Afzel., and the typical Collemaceæ. (Cf. Plate VI. Fig. 35, and Plate III. Fig. 22. Also Plate VI. Fig. 34, and Plate VII. Fig. 36.)

At this late date it hardly seems necessary to dwell at much length upon the method of reproduction of the true Collemaceæ. The clear-

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* Tuckerman, Genera Lichenum, p. 57.

ness of Stahl's account, emphasized as it is by numerous figures, has seemed to preclude the necessity for further confirmation. It was not so with regard to the heteromeric lichens. Neither Stahl's observations on this point, nor those of his followers, seemed to me sufficiently definite to warrant their acceptation without further confirmation. I therefore attempted this task in those groups of lichens which exhibit the most marked affinities to the Collemaceæ. But failing to discover there the points which I had been led to expect might well be found, I hesitated about accepting without further proof even the clearness of Stahl's statements in regard to the Collemaceæ. I have therefore been led to attempt a confirmation of these statements satisfactory to myself, with the following result. I have examined specimens of *Physma Mülleri*, Hepp. (*Collema myriococcum*, Ach.) ; *Collema chalazanum*, Ach. (*Lempholemma compactum*, Krb., *Physma compactum*, Mass.) ; *Collema pulposum*, Ach. ; *Collema nigrescens*, (Huds.) Ach. ; and *Leptogium myochroum*, (Ehrh., Schaer.) Tuck. (*L. saturninum*, Nyl., *Mallotium tomentosum*, Krb.) ; and although I have not carried my observations as far as did Stahl, I have established in all cases the essential point, — the existence within the thallus of a coiled ascogonium prolonged upwards in the form of a multicellular thread, the trichogyne, whose tip appears above the surface of the thallus.

Collema chalazanum, Ach.

In sections through a young apothecium of this lichen, identical according to Nylander with *Physma compactum*, Mass., it is by no means difficult to detect, generally close to the denser investing tissue of the apothecium near the base, one or more structures identical with those figured and described in this species by Stahl as trichogynes. (Plate VII. Fig. 36.) They are delicate septate threads no larger than the ordinary fungus-hyphæ, but at once distinguishable from them by the thickening of the septa, more marked near the surface of the thallus than below. I have never seen more than four such hyphæ in one section, and generally there are but one or two, nor in a thin section should we expect to find more than this, since, according to Stahl, at the base of one spermogonium arise only six or eight trichogynes in all. Inasmuch as these peculiar hyphæ originate in a system of larger cells occupying the base of the young fruit, and reach the surface only at some distance from it, it is very rarely that the plane of the section corresponds exactly to that of a trichogyne, thus making it possible to trace the continuous course of the latter from its point of origin up to the projecting tip. I was also unable to follow the process

of the transformation of the spermogonium into an apothecium, for the reason that in the specimens examined by me the characteristic structure of the spermogonia had almost entirely disappeared, and nothing but rather advanced stages of apothecial development were to be found. In the case of *Physma Mülleri*, however, there could be seen, projecting from the sides of the upper part of the young apothecia, traces of sterigmata. (Plate VII. Fig. 37.) I found that treatment with potassic hydrate, a solution of iodine and potassic iodide, and subsequently with dilute nitric acid, gave the best results in these and the following species, in bringing out the course and structure of both hyphæ and trichogynes, the iodine coloring them a deep brown, while the nitric acid, without destroying this coloration, partially dissolves the investing gelatinous sheaths of the algæ, enabling us to see the hyphæ with much more distinctness.

The peculiar process of ascus formation at the base of the spermogonium, as seen by Stahl and hinted at in my own observations, was established by Stahl as characteristic of the genus Physma, Mass., represented by the species *P. franconicum*, *P. compactum*, and *P. myriococcum.* On other than carpologic grounds, however, recent writers have placed these species in the genus Collema, the first and second under the name *C. chalazanum*, the third as *C. myriococcum*, and even this form, it is stated, may prove to be identical with *C. chalazanum.** Of the two remaining species of this old genus Physma,† *P. sanguinolentum*, Krmph., and *P. Mülleri*, Hepp, the former has been described by Koerber, but the description is not sufficiently definite to place the species with any certainty, although Koerber states that it resembles *Heppia adglutinata*, (Krmph.) Mass. [*H. Despreauxii*, (Mont.) Tuck.]. Specimens of *H. Mülleri*, Hepp, exist in the Hepp herbarium,‡ and I have been fortunate enough to be enabled to examine and compare the specimens. It is undoubtedly a Collema, very closely resembling in habit *C. myriococcum*, (Ach.) Arn., as well as *C. chalazanum*, Ach. The thalline structure agrees rather more closely with my specimens of the latter, while the spores are considerably smaller than the measurements given by Nylander for *C. chalazanum*, and agree with the authentic spore measurements of *C. myriococcum.* The spores of *P. Mülleri* measure 9.4–11.3 $\mu \times$ 7.5–9 μ, are uniseriate in the asci and round-elliptical in shape, thus agreeing exactly with the spores of *C. myriococcum.* We may then with considerable certainty consider

* Tuckerman, Synopsis of North American Lichens, p. 143.

† Koerber, Parerga Lichenum, p. 409.

‡ Lich. Helvet. Exsic. Schaerer and Hepp, No. 933.

Physma Mülleri to be a form of *Collema myriococcum*, leaving the identity of the latter species with *C. chalazanum* an open question. In examining specimens of *Physma Mülleri* I have found a type of reproduction identical with that seen in *C. chalazanum*, a spermogonium at the base of which arise ascogonic cells prolonged outside of the spermogonium in the form of trichogynes. (Plate VII. Fig. 37.) The septa of the trichogynes exhibiting a progressive process of thickening from above downwards, the sprouting of the ascogenous cells to form asci, the pushing aside and suppression of the sterigmata by the growing asci and paraphyses, and the final transformation of the spermogonium into an urceolate apothecium embedded in the thallus, are points which may be readily seen and followed in the species before us, and they serve still further to connect it with *C. chalazanum*.

We are now in a position to adopt one of two views. It has been shown that all the species of the genus Physma, Mass. (with the possible exception of *P. sanguinolentum* Krmph.) are, according to accepted methods of classification, to be grouped together as one or possibly two species of Collema. We find, however, that these two species present a distinct type of reproduction, essentially unlike that of many other species of Collema. We must therefore conclude, either that this is really a generic distinction, in which case the present genus Collema must be divided, or else that in the one genus we have at least two modifications of the sexual type of reproduction seen in certain of the Florideæ. The latter seems at present the more expedient. As yet the sexual reproduction of certain lichens has not been accepted as a basis of classification, and should it be so accepted certain species at least of Leptogium would have to come under Collema, while Collema would lose one or more species in favor of a new genus. A much more extended knowledge of the gelatinous lichens must exist before we can venture to state even that these two modifications of the type of reproduction are the only ones which exist in the Collemaceæ.

I have further followed Stahl's investigations upon certain species of Collema and Leptogium in which the spermogonia and apothecia are separate, and the ascogonium exists as a simple coiled hypha reaching the surface by means of a multicellular trichogyne, and, together with the neighboring hyphæ, developing directly into an apothecium. Among the lichens provided with a cortex I have examined only *Leptogium myochroum*, (Ehrh., Schaer.) Tuck., and it is only necessary to state that the points observed by me have been entirely confirmatory of the results obtained by Stahl from his study of this species and of *L. microscopicum*. Here again, in the face of Stahl's

accurate account, I do not consider it necessary to occupy time and space in describing the process in detail. The figure (Plate VIII. Fig. 38) represents with sufficient accuracy the structure and general appearance of the ascogonium and trichogyne. The same remarks apply to *Collema pulposum*, (Bernh.) Nyl., and *Collema nigrescens*, (Huds.) Ach. The latter gives peculiarly good results, showing that the stages of development from the formation of the ascogonium to that of the mature spermogonium agree exactly with those described by Stahl in *C. microphyllum*, Ach. Sections made near the margin of the thallus, which is generally beset with young apothecia, show large numbers of primordia consisting of a large-celled coil invested more or less closely by branches of the neighboring hyphæ, lying between the young apothecia. (Plate VIII. Fig. 41.) Coils not yet thus invested are more rarely seen. They do occur, however, and the following points may readily be established. (Plate VIII. Fig. 40.) With iodine they do not turn blue, but give a very pronounced protoplasmic reaction. They arise directly from an ordinary thallus hypha, form two or three spiral coils, and are then prolonged upwards in the form of a straight or curved multicellular trichogyne. The tip rises above the surface, swells considerably, and is cut off by a cross wall arising at the base of the swollen portion. I was unable to see the act of fertilization, or the subsequent changes in the trichogyne, but the later development corresponds exactly with that of *C. microphyllum*.

It is possible now to summarize our knowledge of the reproductive process in the Collemaceæ as follows, bearing in mind that this list includes all the species thus far studied, and only those: —

I. Type characterized by the transformation of the spermogonium into an apothecium after the fertilization of the carpogonium.

Physma franconicum, Mass. " *compactum*, Mass.	= *Collema chalazanum*, Ach.
" *myriococcum*, Mass.	= *Collema myriococcum*, Ach.
" *Mülleri*, Hepp,	= *Collema myriococcum*, Ach.

II. Type characterized by complete separation, throughout their course of development of spermogonia and apothecia.

Leptogium Hildenbrandii, Nyl. " *Menziesii*, Nyl. " *saturninum*, Nyl. *Mallotium tomentosum*, Krb. *Collema tomentosum*, Hoffm. " *saturninum*, (Dicks.) Ach.	= *Leptogium myochroum*, (Ehrh., Schaer.) Tuck.

Collema microphyllum, Ach.
Synechoblastus conglomeratus, Krb. = *Collema conglomeratum*, Hoffm.
Collema multifidum, (Scop.) Krb.
" *pulposum*, (Bern.) Nyl.
" *nigrescens*, (Huds.) Ach.

The work for the future must be the careful examination of all forms of gelatinous lichens, and the accurate observation of all types of reproduction found to occur in the group.

Summary of Results.

1. My investigations upon the Collemaceous genera Leptogium and Collema, under which latter genus are to be included the forms described by Stahl under the name Physma, Mass., are entirely confirmatory of the results arrived at by Stahl in his investigations upon those groups. There exist in the Collemaceæ at least two modifications of a sexual type of reproduction, one monoclinic, of which *Collema chalazanum*, Ach., is a typical example, the other diclinic, exemplified by *Leptogium myochroum*, (Ehrh., Schaer.) Tuck., and *Collema nigrescens*, (Huds.) Ach.

2. The genus Hydrothyria, represented by *H. venosa* Russ., cannot, as heretofore, be considered as typically Collemaceous, but is to be regarded as transitional in its character, and related to the genera Peltigera and Pannaria, between which it forms a more or less definite link.

3. In the groups of typically heteromeric lichens more nearly related structurally to the Collemaceæ, as well as in the transitional forms represented by Pannaria, Heppia, and Hydrothyria, there exists, so far as I have seen, no visible evidence of any sexual form of reproduction. The development of the fruit is a purely vegetative process analogous to that seen in many Ascomycetous fungi.*

4. In all such lichens, as far as my observation goes, there exists at no stage in the development of the fruit any differentiation of the hyphæ into an ascogenous system and an enveloping system distinct from it.* Both asci and paraphyses arise from one and the same system of hyphæ, and with respect to their origin exhibit the closest

* Pleospora. Miyabe, "On the Life-History of Macrosporium parasiticum, Thüm.," Annals of Botany, Vol. III. No. IX. pp. 10, 24.

Claviceps, Epichloe, and Nectria. De Bary, Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria, English translation, p. 200.

Sphyridium, Cladonia, and Bæomyces. Krabbe, "Entwicklung, Sprossung und Theilung einiger Flechtenapothecien," Botanische Zeitung, 1882.

mutual relationship, thus presenting a marked analogy to those Ascomycetous fungi in which the fruit arises as the result of a purely vegetative process of hyphal growth.

In conclusion, I must express my thanks to Dr. W. G. Farlow who, during the course of my investigations, very kindly allowed me the free use of his herbarium and library.

EXPLANATION OF THE PLATES.*

Plate I.

Figs. 1–3. *Sticta anthraspis*, Ach. Asci and paraphyses after treatment with iodine. × 500.

Figs. 4–6. *Sticta amplissima*, (Scop.) Mass. Asci and paraphyses after treatment with iodine. × 500.

Figs. 7, 8. *Peltigera polydactyla*, (Neck.) Hoffm. Asci and paraphyses after treatment with iodine. × 500.

Figs. 9–11. *Nephroma tomentosum*, (Hoffm.) Krb. Asci and paraphyses after treatment with iodine. × 500.

Plate II.

Pannaria molybdea, (Pers.) Tuck.

Fig. 12. Cross-section of margin of thallus with immature apothecium. × 110. The outline is drawn with the camera, the detail being drawn free-hand.

Fig. 13. Portion of an older hymenium near the margin, with asci, paraphyses, and subhymenial tissue. Free-hand drawing, partially diagrammatic.

Figs. 14–16. Asci and paraphyses. × 500.

Fig. 17. Isolated gonidia. × 500.

Plate III.

Pannaria rubiginosa, (Thunb.) Delis.

Fig. 18. Portion of immature apothecium. Free-hand drawing, partially diagrammatic.

Fig. 19. Isolated colonies of gonidia. × 500.

Figs. 20, 21. Asci and paraphyses, after treatment with a very dilute solution of iodine and potassic iodide. × 500.

Fig. 22. Cross-section of thallus. The outline drawn with the camera, the detail completed free-hand. × 140.

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* The drawings in all cases, unless otherwise stated, were made with the aid of the camera lucida. The paraphyses are colored darker by the iodine than the cells from which they arise.

Plate IV.

Figs. 23–25. *Heppia Despreauxii*, (Mont.) Tuck. Asci and paraphyses. × 1100.

Figs. 26, 27. *Hydrothyria venosa*, Russ. Asci and paraphyses after treatment with iodine. × 500.

Figs. 28–30. *Hydrothyria venosa*, Russ. Young paraphyses with bridge-like connections. × 500.

Plate V.

Hydrothyria venosa, Russ.

Fig. 31. Cross-section of vein and portion of thallus. × 140.

Fig. 32. Cross-section of double apothecium. Free-hand drawing.

Fig. 33. Isolated gonidia. × 1025.

Plate VI.

Fig. 34. *Physma byrsæum*, (Afzel.). Cross-section of a thallus 0.9 mm. thick, showing only the upper and lower surfaces. × 140.

Fig. 35. *Physma luridum*, (Mont.). Cross-section of thallus. × 140.

Plate VII.

Fig. 36. *Collema chalazanum*, Ach. Cross-section of young apothecium, with trichogynes. × 140.

Fig. 37. *Physma Mülleri*, Hepp. Cross-section of young apothecium occupying a spermogonial cavity with portion of a trichogyne. × 140.

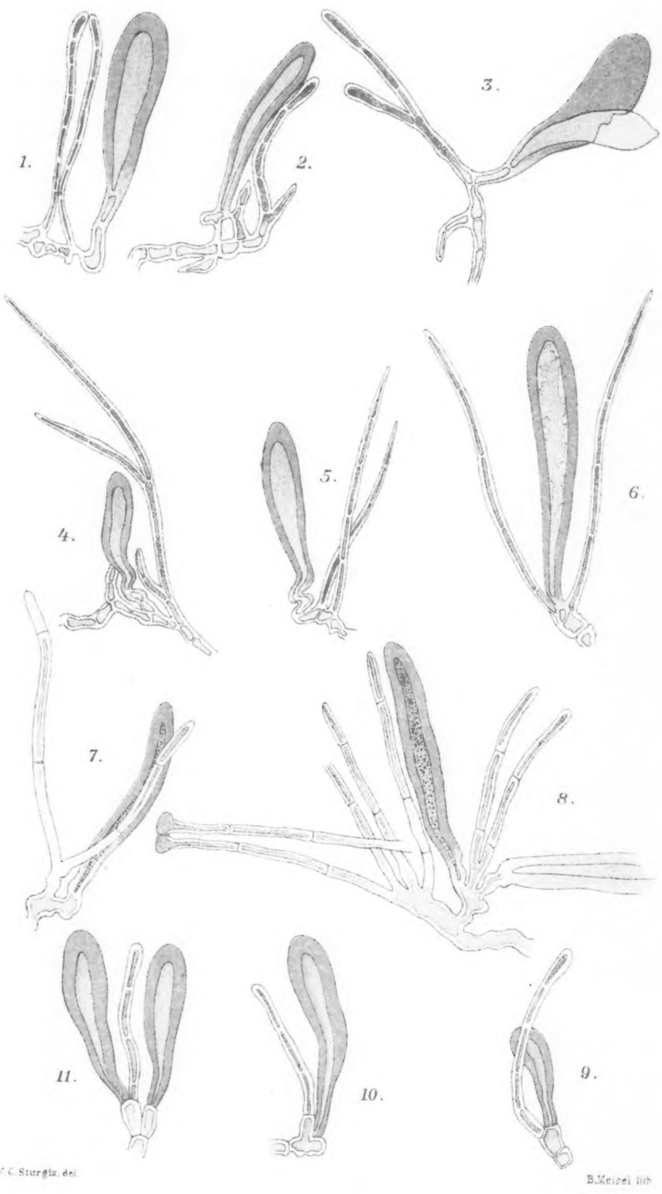
Plate VIII.

Fig. 38. *Leptogium myochroum*, (Ehrh., Schaer.) Tuck. Ascogonium and portions of two trichogynes. × 500.

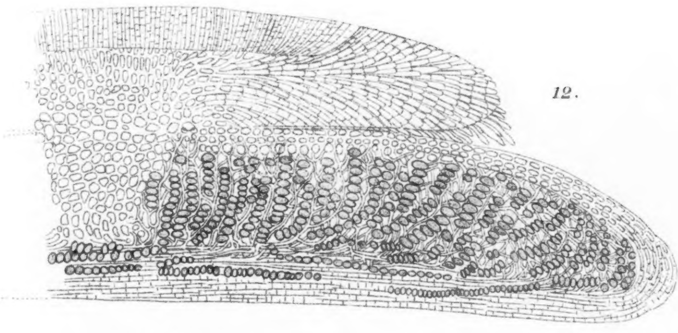
Fig. 39. *Collema pulposum*, (Bernh.) Nyl. Ascogonium. × 500.

Fig. 40. *Collema nigrescens*, (Huds.) Ach. Young ascogonia. × 500.

Fig. 41. *Collema nigrescens*, (Huds.) Ach. Older ascogonium partially enveloped by the surrounding hyphæ. The hyphæ which rise toward the upper surface of the thallus already show a definite parallel arrangement. × 500.



W. C. Sturgis, del. B. Meisel, lith.



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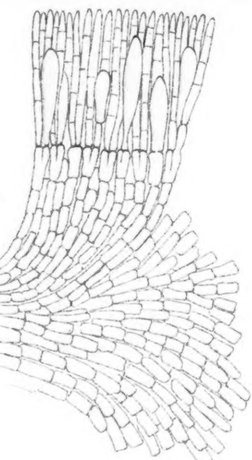

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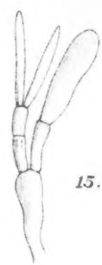

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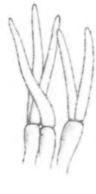

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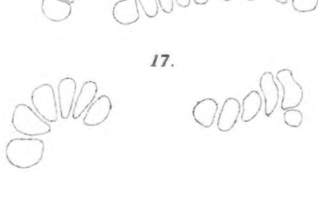

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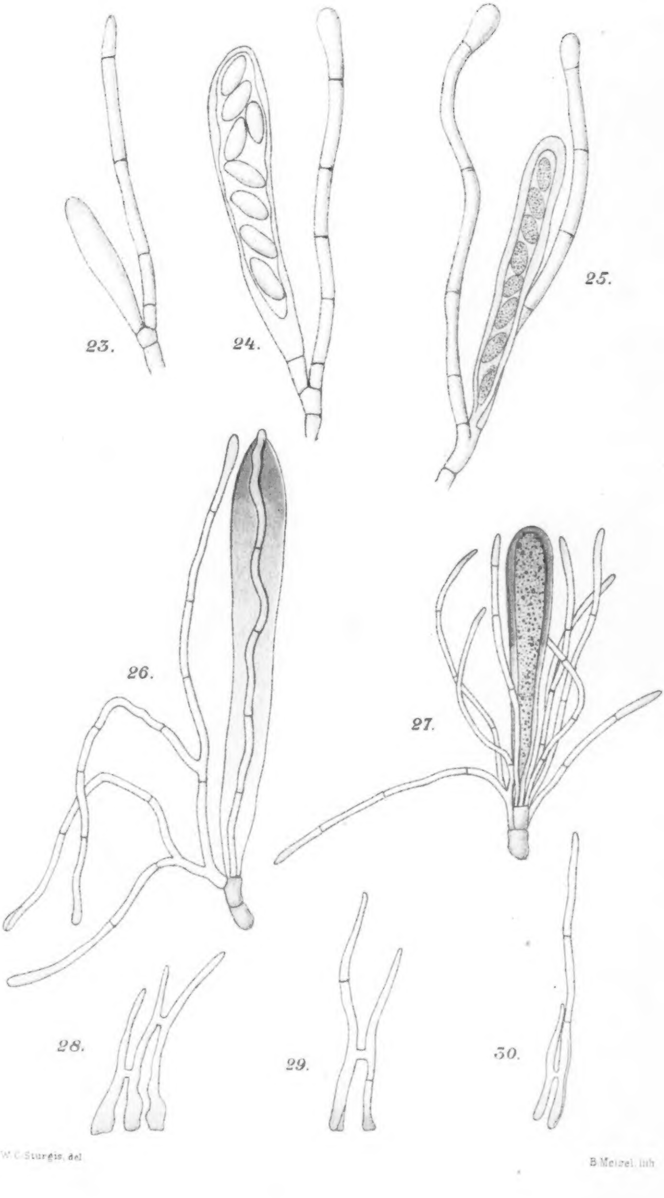
W. C. Sturgis, del.

B. Meisel, lith.



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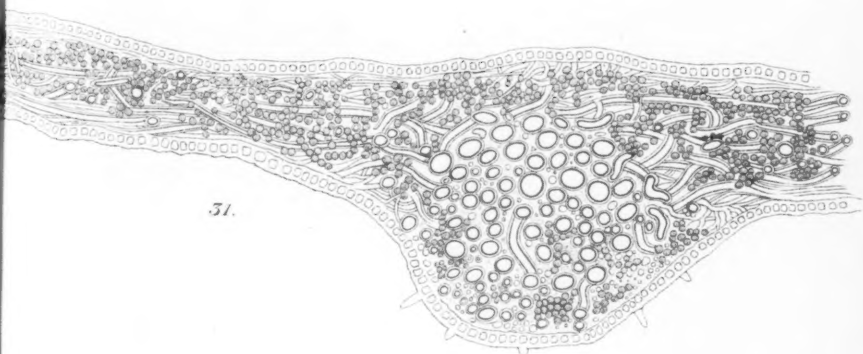

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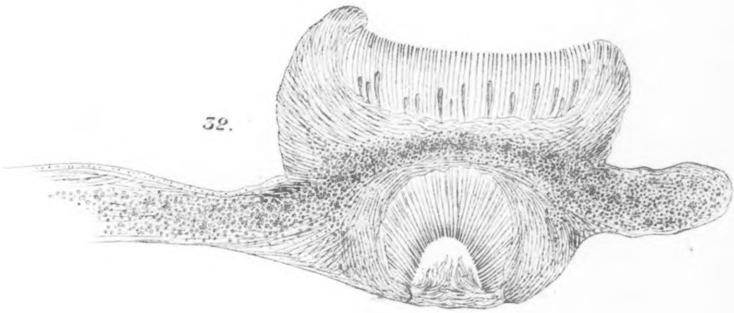
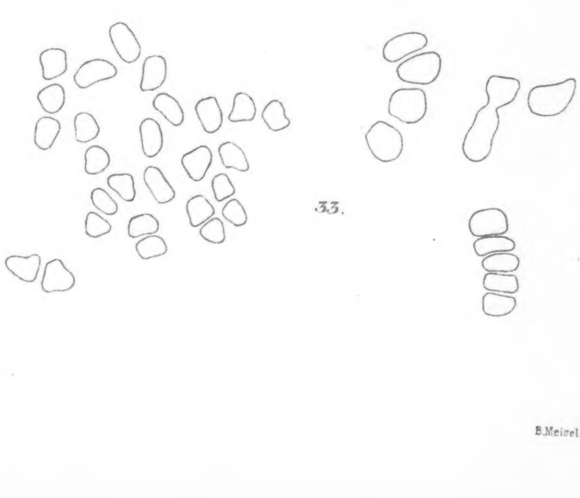


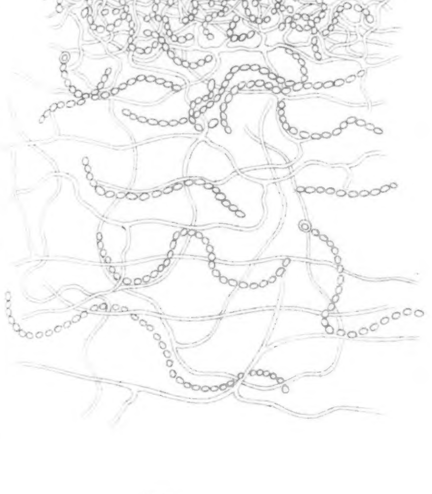
32.



33.

W. C. Sturgis, del.

B. Meisel, lith.



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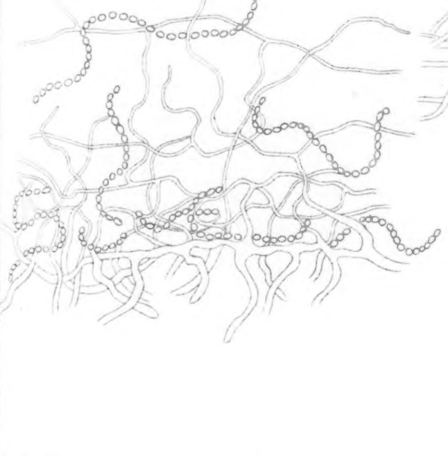
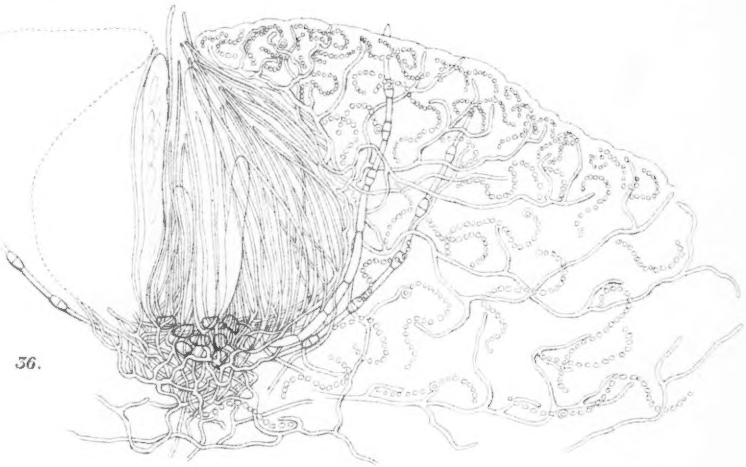


35.

[illegible] del.

B. Meisel lith.



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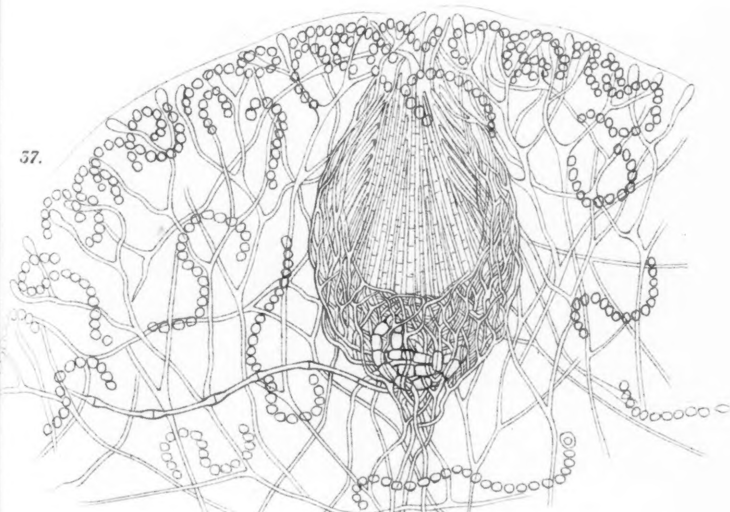
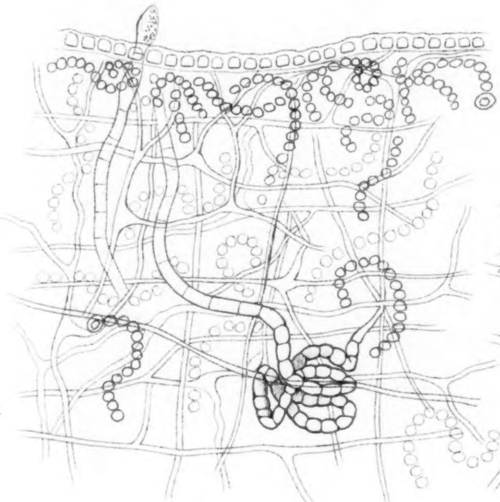


W. C. Sturgis, del. B. Meisel, lith.



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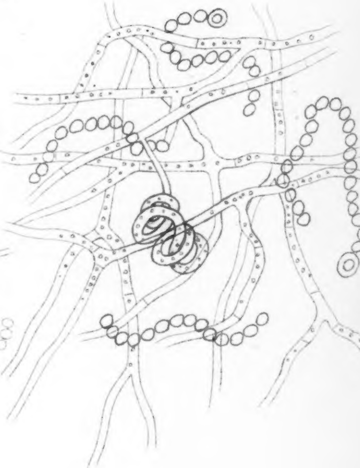

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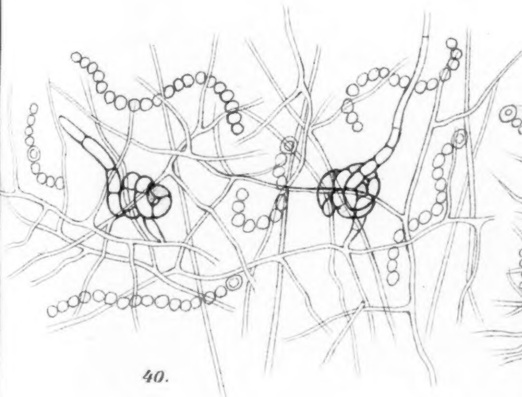

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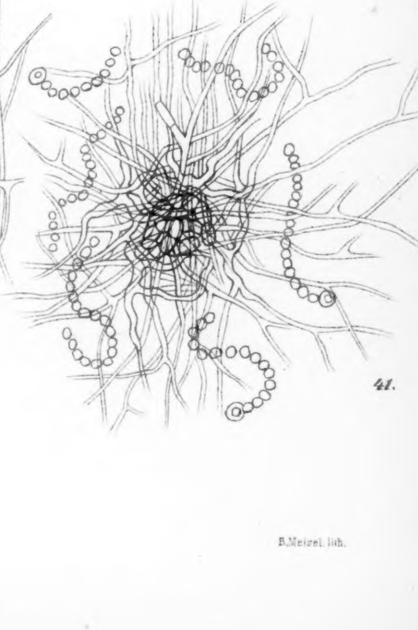

41.

W. C. Sturgis, del.

B. Meisel, lith.

IV.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY.

XII. — CONCERNING THE STRUCTURE AND DEVELOPMENT OF TUOMEYA FLUVIATILIS, Harv.*

By William Albert Setchell.

Presented by W. G. Farlow, April 9, 1890.

The generic name *Tuomeya*, bestowed by Harvey upon a rare and curious fresh-water alga sent him from the United States, commemorates a diligent collector and contributor to the work on the Nereis, Professor Tuomey of Alabama. Harvey mentions that *Tuomeya fluviatilis*, as the species was named, had been collected in a river in Alabama by Professor Tuomey, and near Fredericksburg, Virginia, by Professor J. W. Bailey. In his general remarks on the suborder *Batrachospermeæ*, however, Harvey mentions New York and Alabama as "distant localities" in which the species had been found. As New York does not appear in the formal list of localities under the species,

* The following statement should be made with regard to the name of the alga whose structure is described in the present paper. The specimens collected by Professor Tuomey were sent originally to Harvey, who described them under the name of *Tuomeya fluviatilis* in the third part of his *Nereis Boreali Americana*, which was accepted for publication in September, 1857, and issued in March, 1858. Meanwhile Harvey had apparently sent a specimen of his plant to Kuetzing, who described and figured it, under the name of *Baileya Americana*, in his *Tabulæ Phycologicæ*, VII. 35, Plate LXXXVII. Fig. 3, of which the title-page bears the date 1857. The generic name given by Kuetzing cannot stand, since there was a genus of *Compositæ* of the same name described by A. Gray in 1848. Whether the specific name of Kuetzing should have preference over that of Harvey may be questioned, considering that, while the date of Volume VII. of the *Tabulæ* is given as 1857, it may not have been distributed until early in 1858; so that the date of Kuetzing's publication and that of Harvey's, so far as the botanical public were concerned, were almost identical. Certainly Harvey could have had no knowledge that Kuetzing was about to describe the specimens originally sent to himself, and, if there seem to be any doubt as to date of publication, under the circumstances Harvey should have the benefit of the doubt. — W. G. F.

we may infer that the reference here is due to a slip on the part of Harvey's memory. He was doubtless thinking of Bailey's plant and forgot, for the moment, that this had been collected in Virginia, and not near Bailey's home in New York.

Many students of American fresh-water algæ since Harvey's time have searched diligently in the hope of rediscovering this most interesting species, but without success. For nearly forty years now, no authentic report of the finding of *Tuomeya fluviatilis* has been published. It is, then, a great pleasure to be able to announce that Mr. Isaac Holden, a diligent student of our American algæ, has found this long lost plant in some quantity in a brook near Bridgeport, Conn. The date of Mr. Holden's first discovery was December 16, 1888. Since then it has been found in several places. Mr. Holden has found it in several other localities near Bridgeport, and at Mount Desert Island on the coast of Maine, nearly three hundred miles distant from Bridgeport. Mr. E. B. Harger also has found it in large quantity in a brook near his home in Oxford, Conn. These several localities added to the two given by Harvey show that the range of *Tuomeya fluviatilis* extends along our whole Atlantic border, from Maine to Alabama, a distance of about twelve hundred miles. We may also expect that it will be found farther inland.*

It will be best, perhaps, before proceeding farther, to give the reasons for considering that our plant is the genuine *Tuomeya fluviatilis* of Harvey. It was first compared with the description which Harvey gives in the Nereis, and was found to agree with it in every respect. Harvey's description, indeed, is so full and so accurate as to leave little room for doubt. But through the kindness of Professor W. G. Farlow of Harvard University, I have been able to examine an authentic specimen, which had been presented to him by Professor

* As the preceding communication was about to go to press, I received information that *Tuomeya fluviatilis* had been found in another locality in New England. On April 3, 1890, Mr. A. P. D. Piguet of Jamaica Plain, Mass., found specimens of it in the town of Sharon, about fifteen miles south from Boston. This locality, the fourth in New England, is situated very nearly halfway between those at Oxford and Bridgeport in Southwestern Connecticut and the one at Mount Desert, Me. I was able, through the kindness of Mr. Piguet, to examine this new locality. The *Tuomeya* was growing in some abundance in a narrow, rocky brook, just below the dam of a small mill-pond. At the place where the plants were growing the current was very rapid. On the same stones with the *Tuomeya* were growing a large *Batrachospermum*, probably *B. Boryanum*, Sirdt., and tufts of a small reddish *Chantransia*, which seems to agree with *C. Hermanni*, Desv. In a few cases specimens of these plants were growing on the specimens of *Tuomeya*.

E. P. Wright, Curator of the Harveyan Herbarium at Trinity College, Dublin. With this specimen, our plant was carefully and critically compared, and was found to agree with it in every point of structure and habit. There can be no reasonable doubt that the specimens received from Messrs. Holden and Harger belong to the *Tuomeya fluviatilis* of the Nereis.

The systematic position of *Tuomeya* is a matter of considerable interest and importance. Harvey says, on page 62 of the Nereis: "The plants referred to this order (*Batrachospermeæ*) naturally group themselves into two suborders, distinguished from each other by the habit of the frond, but closely related in structure and fructification, and as it seems to me inseparably connected by the genus *Tuomeya*, which unites in itself the characters of the seemingly so dissimilar genera *Batrachospermum* and *Lemanea*." An exact knowledge of the relation which *Tuomeya* bears to *Lemanea* and *Batrachospermum* respectively, requires a careful comparison of the details of the structure and development to be found in these three genera. As Harvey had only a few dried specimens of *Tuomeya* at his disposal, he did not undertake to do this. Indeed, he remarks that he had not even ventured to make a drawing from them. Dried specimens, as far as my experience goes, are peculiarly unsuitable for study, as the various cells do not recover their original size and shape at all well. The manipulation of plants which have been long dried is a difficult and unprofitable task. Specimens which have been preserved in weak alcohol (of a strength of about fifty per cent) are much better for the purpose, but the hardening of the elements produced by the alcohol imparts a rigidity and a brittleness which are detrimental to obtaining the best results. Fresh material is readily prepared for the microscope, and shows the details both of structure and development most satisfactorily. The work whose results are summarized below has been done entirely upon the living specimens, and the author has thus been able to obtain a more complete knowledge of the life history of *Tuomeya* than would have been possible under any other circumstances. Through the kindness of Mr. Holden, he has been supplied at frequent intervals with fresh specimens, not only of *Tuomeya*, but of various species of *Lemanea* and *Batrachospermum* as well. With such facilities, it has been possible to compare the structure and development in these genera, point for point, and to determine with a certain degree of definiteness the exact relation existing between them.

The method of investigation has been a comparatively simple one.

If a small portion of the upper part of a branch be gently crushed between a slide and a cover-glass, one can readily see all the principal stages in the growth from the apical cell, even to the production of the complexity of the adult frond. By a judicious agitation of the cover-glass by tapping gently, the various sets of cells may be made to separate in such a fashion as to show all the lesser details. The old frond is so dense as to be crushed with some difficulty, and in the process the relations are often more or less obscured. Therefore sections are a necessary aid to understanding the structure of such portions, but can be made in any direction with considerable ease. During the investigation of the development of the frond, the sexual organs and developing fruit were discovered and carefully studied. By this, we are enabled to make our comparison more thorough and more exact.

Tuomeya fluviatilis is found in brooks or small streams, and seems to prefer those windings of the course or declivities in the bed where the current is accelerated. It grows for the most part on smooth stones or rocks, clustered together in considerable numbers. In a few cases, Mr. Holden has found it growing upon grasses. When kept in the house, *Tuomeya* generally flourishes well, if the temperature be not too high, and if it has an occasional supply of fresh water. It often puts forth new branches under such circumstances, and one lot even produced the sexual organs.

In regard to the general habit of the plant, Harvey's description can hardly be improved upon. It scarcely ever reaches a height of over two inches (5 cm.), is pyramidal or irregularly conical in general outline, and decidedly bushy (cf. Fig. 1). The plant is comparatively rigid, and does not collapse on being removed from the water. In this respect, it differs much from the larger specimens of *Batrachospermum*, which it greatly resembles in size, color, and manner of growth, and with which it very frequently grows. Indeed, it is often difficult to tell *Tuomeya*, when growing, from one of these larger *Batrachosperma*, unless one touches the specimen or takes it from the water. The *Tuomeya* then remains firm and retains its shape, while the *Batrachospermum* utterly collapses and becomes a shapeless gelatinous mass. The younger branches of *Tuomeya*, however, are often very slender, and then generally droop considerably on being withdrawn from the water, but to no such extent as is characteristic of the *Batrachosperma*. When dried, specimens of *Tuomeya* seem to be decidedly cartilaginous, resembling in this respect specimens of *Ahnfeldtia plicata*. They do not adhere closely to paper, even after

being subjected to a considerable pressure. In this respect, as well as in all others depending upon consistency, *Tuomeya* resembles more closely the rigid *Lemanea* rather than the gelatinous *Batrachospermum.*

From a discoidal base, which is often three sixteenths of an inch (5 mm.) in diameter, there generally arises a stout stem, which is soon lost above in the numerous long main branches. This stem often reaches a diameter of a little over a sixteenth of an inch (2 mm.). Harvey's expression, "Frond . . . scarcely as thick as a hog's bristle," refers of course only to the condition in the dried specimens from which his description was drawn.

The branching is monopodial, and is quite irregular, being, as Harvey says, "alternate or secund, scattered or crowded." The branches, which are long and somewhat flexuous, are from five to six times branched. The axils are usually patent, and the ultimate ramuli are rather numerous, comparatively short, and more or less subulate. According to the description in the Nereis, these ultimate ramuli are "slightly constricted at the insertions, and taper to an obtuse point," but these characters are not always prominent in the dried specimens in my possession. At the very base the stem and the main branches are irregularly cylindrical, while farther up the branches are generally nodose, which appearance is usually rendered more conspicuous in drying. Toward the tip the branches are quite regularly cylindrical, and at the very apex are bluntly conical, or at times acute.

When the tip of a branch or branchlet is examined with a power ot about five hundred diameters, it is seen to be composed of a cluster of more or less erect microscopic filaments, from the centre of which projects the short, stout main filament to a height of from 16 to 20 μ (cf. Fig. 2). This main filament is composed of a single row of cells placed end to end, and terminates in a cell which is in a state of active growth. This apical cell is, in most cases, bluntly conical in shape, and measures from 6 to 8 μ in height, and from 4 to 6 μ in basal diameter. Lining the external wall is a thick, dense chromatophore, but the contents of the central portion, as seen in a median optical section, are colorless. From the base of the apical cell, new cells are cut off by horizontal partitions, and the cells thus cut off are in shape discoidal, measuring usually only 2 to 3 μ in height, while the diameter equals 10 to 12 μ. The second or third cell from the tip generally has a small lateral protuberance, or perhaps two or three protuberances side by side, covering only a small fraction of the external wall. The next two or three cells lower down also

usually have protuberances of the same size and shape, and the protuberances of all these cells are usually in the same vertical row or rows. This gives the protruding filament, when seen in side view, the appearance of being straight and unmodified along one margin, but more or less irregularly nodose along the other (cf. Figs. 3 and 11).

As the protuberances increase in size and begin to elongate, they become separated from the parent cell by a tangential wall. These side cells form two or three new cells at their tips by a sort of budding process. Two or three small papillæ make their appearance on the free end of the cell, gradually increase in size, become constricted, and are finally cut off by a division wall (cf. Fig. 4). Each of the new cells proceeds to grow in a similar fashion, and so we soon have developed from each protuberance a di- or trichotomously branched ramellus, which spreads out in all directions from the point of attachment. During this process, new protuberances have been developing on the same cells with those first formed, and have also been growing out into ramelli, so that finally each cell of the main filament has several (in most cases four) ramelli attached to it. As the ramelli elongate, the basal cells increase in size, and as their basal diameter increases they occupy more and more of the circumference of the parent cell, until, when well developed, they completely encircle it. The four ramelli then form a whorl, each ramellus being situated at right angles to its neighbor.

During the process of the formation of the ramelli, the axis has been actively growing, new cells have been forming at the tip, and the older cells of the axis have been elongating upwards. As these cells elongate, the whorls of ramelli remain at the very uppermost portion. As the main cells elongate, they also become somewhat swollen, and hence moniliform, there being a constriction formed at the junction of two cells. Consequently the basal cells of the ramelli, since they are situated on the extreme upper portion, are attached to one side of this constriction. As they enlarge, they necessarily touch the other side of the constriction with a portion of the lateral wall, and grow to it. In this way the basal cells of the ramelli become attached to two cells of the axis. The point where two axial cells join may conveniently be called the node, and the axial cells themselves may be termed the internodes.

The ramelli undergo several important changes as they develop. At first, the cells composing them are all small and nearly of the same size and shape. They are also provided with large and solid chro-

matophores (cf. Fig. 6). As the ramellus elongates, the proximal cells gradually become somewhat swollen. They are finally broadly spheroidal in shape, filled with a reticulated mass of protoplasm and with a few small lenticular-shaped chromatophores (cf. Fig. 7). This causes them to appear as large and transparent sacs, forming a stratum adjoining the axis. As we go toward the outer end of one of the more adult ramelli, the cells grow smaller, they possess more abundant and larger chromatophores, and hence the outer strata of cells appear denser and darker colored. The transition from one stratum to the other is in most cases decidedly abrupt. This appearance of an inner transparent layer, sharply defined from an outer dark layer, is visible to the naked eye. In rather old portions of the plant, the very end cells, which in such places are of course very numerous, become elongated and cylindrical, and so appear to clothe the frond with a layer of fine filaments.

During their growth, the branchlets of the ramelli intertwine with the branchlets of the ramelli both of the same and of adjacent whorls, and this takes place to such an extent as to form a dense mass of cells about the axis, separated from it by a small space, and connected with it only at the nodes by the basal cells of the ramelli. We have thus a hollow cylindrical frond formed about the axis, composed of two sets of cells, much resembling the structure in the fronds of certain species of *Lemanea*. When a portion of such a frond is crushed, the peripheral wall of the cylinder separates, and leaves the axis in pieces of considerable size.

But before this cylinder is fully formed, and even as soon as the internodal cells have elongated sufficiently to separate well the whorls of ramelli, another complication of the structure arises. Filaments are given off from the basal cells of the ramelli, which differ decidedly in appearance from the ramelli arising from the same cells. While the ramelli are more or less moniliform and regularly di- or trichotomously branched, these filaments are uniformly cylindrical, and for the greater part simple. While the ramelli grow outwards and away from the axis, these new secondary filaments have a downward course, and apply themselves closely to the axis, twining about it in such a manner as finally entirely to hide the cells of which it is composed. Some of these secondary filaments may originate from the more distal cells of a ramellus, and in the older portions, many of them thus arising may grow obliquely outwards, as well as downwards. In very old stems, it frequently happens that several of these filaments, intertwined so as to form a strand, proceed obliquely downwards

to the surface of the frond, and even beyond it. Some were found to project beyond the surface of the frond to a distance of over a quarter of an inch (about 6 mm.). These strands appear to be of an adventitious nature, and may perhaps become attached to some support and grow into new plants. The filaments have the power of developing into branches, and this fact leads me to think that new plants may be produced from the strands. I have had little opportunity of making observations on growing plants, and consequently have not been able to verify this supposition. But the plants of *Tuomeya* are accustomed to grow in small bunches, the individual plants of which seem to be attached to one another by stolon-like stems. Such outgrowths are not uncommon both in *Lemanea* and *Batrachospermum.*

In the older portions, the walls of these secondary filaments become thickened, and the filaments themselves become so numerous as completely to fill up the space between the axis and the inner portion of the cylinder mentioned above. Thus we have formed a comparatively solid frond. In Figure 10 is given a camera drawing of a portion of a section across such a frond. At *a* is the cross-section of the internodal cell, which occupies the centre of the section. Around *a* are seen the cross and oblique sections of the cluster of secondary filaments, here labelled *b*, which are entwined about *a*. At *c* is represented the "inner peripheric stratum" of Harvey, which can be seen to be portions of a ramellus, whose next portion, *d*, shows smaller elements more densely compacted together. The cells of the two outer rows (*e*) are elongated and cylindrical, and form the "coat of moniliform filaments" which Harvey refers to as the "second peripheric stratum." The drawing was made from a section, which, while fresh, was carefully compared with a similar section from Harvey's plant, and which was found to agree with it in every respect.

We are now ready to compare the structure of the frond of *Tuomeya* with that of *Lemanea* and *Batrachospermum*. In all three genera, the growth is from an apical cell. In *Tuomeya*, as we have seen, this is borne on a protruding filament, which has the young ramelli clustered about its base in the form of microscopic filaments. The same is true of *Batrachospermum*, in which the first stages of growth from the apical cell are almost identical in every respect with those of *Tuomeya*. *Lemanea* has apparently an entirely different mode of growth, although on careful study it is seen to be in accordance with the same plan. A filament of *Lemanea* ends in a single row of two or three cells, and the first lateral cells are divided off in the same

order and in the same directions as in *Tuomeya* and *Batrachospermum.* But in *Lemanea* these lateral cells do not grow out into distinct and separate ramelli, but remain as members of a solid tissue which finally develops into the tubular frond characteristic of *Lemanea.* At the tips, then, of the branches and branchlets, the frond of *Tuomeya* is essentially like that of *Batrachospermum,* and unlike that of *Lemanea.* But its adult structure is just the opposite. *Batrachospermum* always retains the whorls, distinct and evident, and never compacted into a structure resembling a cortex. *Tuomeya,* on the contrary, as we have seen, by the dense growth of the ramelli and the intertwining of their branchlets produces at a comparatively early period a hollow and cylindrical frond, very much resembling that of a *Lemanea.* It lacks completely, however, the highly specialized lateral tubes so characteristic of that genus.

The growth of the secondary filaments in *Tuomeya* agrees with that of the secondary filaments in *Lemanea.* In *Batrachospermum* the secondary "corticating" filaments frequently branch in many species, and the branches resemble very closely those of the ramelli; but in *Tuomeya* and *Lemanea* they branch only at rare intervals, and, becoming very much thickened, materially increase the rigidity of the axis. The secondary filaments in *Tuomeya,* however, are not so completely modified as those of *Lemanea.* They retain some active vegetative functions, and have some special duties, as will be seen later.

In the younger portions of a frond of *Tuomeya,* the branches originate in a uniform manner, but in an irregular sequence. Here a branch usually takes the place of a ramellus, or of some portion of a ramellus. The first evidence we have that a branch is about to be formed is the appearance, as one of the members of a whorl, of a short filament, resembling the apical protruding filament of the tip of a branch, such as is mentioned above. This short filament increases in length, and soon has the protuberances along one side which are to grow out into the ramelli. In the forming branches, the protuberances are usually borne along the lower surface (cf. Fig. 5). In the older portions, the branches originate in a somewhat different fashion. A filament, resembling one of the secondary filaments, grows out in more or less of a horizontal direction, and when about to protrude beyond the surface of the frond begins to develop in the same fashion as a young branch (cf. Fig. 11). Young branches may also take their origin from the more distal cells of a ramellus.

Whenever the tip of a branch is injured, and its apical growth con-

sequently checked, there is always an active production of branchlets in the immediate vicinity of the injury, so as to form a fasciculate cluster of branchlets at the tip. The same thing occurs also in a very striking fashion in *Lemanea*, as well as in *Batrachospermum*. The great facility with which branches may be put forth from any portion of the frond is a very noticeable feature in *Tuomeya*.

In manner of branching, which has much to do with general habit, *Tuomeya* follows *Batrachospermum* more closely than it does *Lemanea*. *Lemanea*, when it does branch frequently (e. g. *L. fucina*, Bory.), branches in a comparatively regular fashion, and the branches are generally alternate or nearly opposite. *Batrachosphermum*, however, branches very capriciously, and is followed in this by *Tuomeya*.

Unfortunately the germination of the spores has not been seen, nor has the opportunity for examining very young plants been given. The examination, early in September, of a few young plants, brought in on the stones to which they were attached, showed what appeared to be a basal layer of cells, whence arose a small turf of short unbranched filaments of a single row of cells each, at whose tips were somewhat swollen cells with decidedly granular contents. These turfs resembled in color and size the basal tufts about a large *Batrachospermum*, appearing to be *B. cœrulescens*, (Bory) Sirdt., which grew on the same stones, but differed in being unbranched, and in possessing the swollen tips to the filaments. These swollen bodies seemed to be very much like the sporules of the *Chantransia*-form of *Batrachospermum* as described by Sirodot. However this may be, it seems very likely that this turf of filaments may be a provision for the production of new plants when the old ones are torn away from it by floating branches, or by ice, or by sand in the current, all of which are active agents in such work, according to Mr. Holden's frequent experience.

The sexual organs and fruit were most diligently sought, both by Mr. Holden and myself, through each successive gathering. We did not however discover them until about the middle of October, but they have since occurred in some abundance. Both the antheridia and the procarps are found on the same plant, but are generally borne on separate portions of the frond. Both kinds of organs develop indifferently on any part of the plant, being found in the older portions as well as in the younger.

The branches which bear the antheridia arise at the nodes, either from the basal cells of the ramelli or from cells near these. These branches then either pass out horizontally to the surface of the frond,

or else, descending through an internode to the next node below, there change their course and proceed out to the surface. Occasionally some of them grow obliquely downwards and outwards, but this method is not a common one. The branches are generally very numerous at a node, and form a dense ring surrounding it.

The antheridial branches are cylindrical, and at first unbranched. At the ends, which are situated at or just beneath the surface of the frond, they are two or three times branched in a corymbosely dichotomous fashion. They are composed of cylindrical cells, two to four times as long as broad, and resemble in general appearance the secondary filaments described above. The contents of the cells, however, are less decidedly green, being more of a bluish-gray color, more homogeneous and granular, and containing no conspicuous chromatophores (cf. Figs. 21 and 22).

The antheridia are borne at the tips of the branches, are spheroidal in shape, of an opaline tint, and with granular contents. In the centre is a large spot of greater refractive properties than the rest of the contents. On being liberated from the antheridium, the single antherozoid is, for a short time at least, of an irregular shape, and has a slight amœboid motion, but it soon becomes globular and motionless. After the antherozoid has been discharged, the basidial cell may grow through into the empty sac of the antheridium and produce there a new antheridium. One frequently finds the antheridium enclosed in two or three ruptured sacs, showing that the process may be repeated several times. A stage of this process is illustrated in Figure 22.

The antheridia in shape, color, and character of contents exactly agree with those of *Batrachospermum*, and in these respects differ from those of *Lemanea*. The antheridia of *Batrachospermum*, however, are borne singly, or in twos or threes, on various cells of the unmodified ramelli. In *Lemanea*, on the contrary, they are all borne at the nodes, and are situated at the tips of a special layer of dichotomous, short filaments. In this, then, as will be seen from the above, *Tuomeya* differs decidedly from *Batrachospermum* and approaches *Lemanea*. The necessity for having the antheridia situated in the external layer in *Tuomeya*, as well as in *Lemanea*, is probably to be found in the possession of a solid frond by both of these genera. If borne in the interior of such a frond, the antherozoids would have difficulty in being carried from plant to plant by the currents. In *Batrachospermum* the difficulty is not so great, yet even here the antheridia are borne on the outer joints of the ramelli rather than on

the inner ones. As far, then, as the structure and position of the antheridia are concerned, *Tuomeya* is rather more like *Lemanea* than it is like *Batrachospermum*.

The female organs are borne upon especially modified procarpic branches. In the axil of one of the ramelli — generally in the younger, growing portion of a frond, but very frequently also in the maturer, older parts of the same frond — arise one or more short branchlets of an appearance very different from any of the other outgrowths from the axis. This branch, for usually there is only one, is made up of broad, stout cells with rather unusually dark chromatophores. As the branch increases in length, it as a general rule becomes spirally twisted (cf. Figs. 12 to 14), and the cells grow out on the convex side into short branchlets (cf. Figs. 13 and 15). This frequently continues until a complex branch is produced. The terminal cell of the branch produces the procarp, which in *Tuomeya* consists of a broadly ovoid trichophore, surmounted by a trichogyne several times longer than itself. The trichogyne is a somewhat elongated lageniform body, about 30 μ high and 10 μ in diameter at the base, and is connected with the trichophore by a slender, elongated pedicel, which is often 10 μ long and 3 μ thick (cf. Figs. 16 to 20, *tr.*). Very frequently the trichogyne is attached to the pedicel obliquely (cf. Fig. 16). The contents of the trichogyne at maturity are clear, and of an extremely light bluish tint. When ready for fertilization, the trichogyne is usually very near to the surface of the frond in the older portions, but in the younger parts of looser structure it often remains very close to the axis.

One, two, or even three antherozoids may often be found attached near the tip of the trichogyne (cf. Figs. 18 and 19). An opening is made by the absorption of the intervening wall, and the contents of at least one of the antherozoids pass into the trichogyne. As a consequence of this, the trichophore, whose contents have already become granular in appearance, begins to put forth buds (cf. Figs. 17 to 19). These buds, which are at first few and comparatively large, gradually become divided into smaller and smaller lobes, until at last there is a considerable number of them arranged in more or less concentric rows upon the surface of the trichophore (cf. Fig. 20). As the cystocarp is thus developing, secondary branches grow toward it from the axis, and, surrounding it, obscure its farther development. As far as could be seen, strings of spores similar to those formed in *Batrachospermum* seemed to be produced.

In most of the species of *Batrachospermum*, especially in those

which have a frond of loose structure, the procarp is borne at the apex of a short branch, which does not differ in any marked way from the other branches. In some of the denser species, however, this branch is somewhat modified. This is particularly striking in *B. densum*, Sirdt. (cf. Sirodot, Les Batrachospermes, Plate XIII. Figs. 6, 9, and 10), where the procarpic branch much resembles some of the simpler ones found in *Tuomeya*. This special branch in *B. densum* is by no means modified to the extent that the majority found in *Tuomeya* are. In *Lemanea* the procarpic branch is very different from any found in *Batrachospermum*, and seems more complicated in some ways than in *Tuomeya*. The procarpic branch in *Lemanea* arises from a cell placed against one of the lateral tubes. It is usually three or four cells long, and bears at the tip an elongated trichogyne which projects externally. The lower cells of this branch, in some species, (cf. Ketel, Anatomische Untersuchungen über die Gattung Lemanea, Inaug. Diss., Berlin, 1887,) produce a number of short branchlets similar to those in *Tuomeya*.

The trichogyne of *Tuomeya* is almost exactly like that of *Batrachospermum*, and yet in some of its various shapes it much resembles the trichogyne of certain of the simpler species of *Lemanea*. It is not, however, modified to any such extent as are the trichogynes of the ordinary *Lemaneæ*. The first stages in the formation of the cystocarp are also essentially like those of the cystocarp of *Batrachospermum*. Therefore, we may say that in the position and structure of the female organs, as well as in the development of the cystocarp, *Tuomeya* approaches certain of the more complex species of *Batrachospermum* on the one hand, and certain of the simpler forms of *Lemanea* on the other, thus occupying, in regard to these structures, an intermediate position between these two genera.

Harvey considered that a solid filamentous axis, coated externally with moniliform filaments, was characteristic of *Batrachospermum*, while *Lemanea* possessed a cylindrical and hollow frond, whose walls were laxly constructed within. *Tuomeya* seemed to him to possess the solid axis of a *Batrachospermum*, shut up within the tube of a *Lemanea*, and coated externally with the filaments of a *Thorea*. Harvey's idea of the relationship is a very good one. The solid axis, to be sure, more nearly resembles that of certain species of *Lemanea*, but in its earlier stages is almost exactly like that of *Batrachospermum*. The frond at one period is a hollow cylinder enclosing this axis, but it has developed like that of a true *Batrachospermum*. In its extreme

later complex structure the frond surpasses anything of the kind found in either of the other two genera. In the structure of the antheridia, *Tuomeya* rather resembles *Batrachospermum*, but in the specialized antheridial branches and their position at the nodes, it comes very near to *Lemanea*. In the possession of a special procarpic branch, *Tuomeya* is like *Lemanea*, but in the development of the fruit it comes very near to *Batrachospermum*. All recent writers have agreed that *Lemanea* and *Batrachospermum* are nearly related, but *Tuomeya*, as may be seen from my comparison, brings them still nearer to one another. It may be a question as to which genus *Tuomeya* approaches most nearly, so very near does it approach to each of them.

It seems best to say a few words here in regard to a plant which has been referred to the genus *Tuomeya* as an additional species. In the Bulletin of the Torrey Botanical Club for 1877 (November), Rev. Francis Wolle describes a new species of alga, found by him at Bethlehem, Penn., which he makes the type of a new genus, under the name of *Entothrix grande*. Specimens were distributed in Rabenhorst's "Die Algen Europas," where by a misprint the name appears as *Entothrix grædis*, n. sp., Wolle. In his "Fresh Water Algæ of the United States," (Bethlehem, 1887,) on pages 53 and 54, and Plate LXVI. Figs. 2 to 8, Mr. Wolle figures and describes this plant, and refers it to the genus *Tuomeya* as *T. grande*, Wolle, distinguished from *T. fluviatilis*, Harv., by its unbranched and tubular frond. I am indebted to Professor Farlow for the privilege of examining the specimens distributed by Rabenhorst, and Mr. Wolle has been so kind as to send me authentic specimens from his own herbarium. Careful sections from both sets of specimens show that this plant possesses the complicated axis, cortex, and lateral tubes characteristic of *Lemanea*, as limited by Sirodot, as well as the hollow frond and cystocarps of that genus. Professor George F. Atkinson of Auburn, Ala., has just published a preliminary note on the synonymy of this species (Bot. Gaz., XIV. 292), and has referred it to *Lemanea* as *L. grandis*, (Wolle) Atkinson. As far as is known, then, there is only one species of *Tuomeya*.*

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* I have very lately received, through the kindness of Professor Atkinson, a copy of the extra issue of his "Monograph of the Lemaneaceæ of the United States," which is to appear in the May number of the Annals of Botany. In this paper, Professor Atkinson gives a full description, with figures, of *Lemanea grandis*, (Wolle) Atk.

I wish, in conclusion, to express my gratitude to those who have aided me in my work, and especially to Professor Farlow and to Mr. Holden, to both of whom I am very greatly indebted.

CRYPTOGAMIC LABORATORY,
HARVARD UNIVERSITY.

EXPLANATION OF FIGURES.

Fig. 1. A portion of a plant of *Tuomeya fluviatilis*, Harv., of the natural size, collected at Oxford, Conn., by Mr. Harger, Nov. 9, 1889.

Fig. 2. A portion of the very tip of a branch, showing the protruding filament with the young ramelli at its base. × 500.

Fig. 3. The protruding filament with the ramelli removed. × 375 × 2.

Fig. 4. Cross-section through the protruding filament about 40 μ from tip. × 375 × 2.

Fig. 5. Portion of a young branch, with ramelli removed by crushing, showing a young branchlet. × 375 × 2.

Fig. 6. Young portion of a branch, showing the axis and two ramelli. The other ramelli have been removed by crushing. About .25 mm. from the tip. × 375.

Fig. 7. A portion of a young branch, showing one ramellus with young secondary filaments just starting forth. × 375.

Fig. 8. Older specimen, showing the origin of the secondary filaments. × 375.

Fig. 9. Older portion, with some of the ramelli removed by crushing, showing a more advanced stage of the ramelli and of the secondary filaments. × 375.

Fig. 10. Cross-section of an adult, solid stem.
a, axial cell.
b, bundle of secondary filaments.
c, inner portions of ramelli.
d, outer " "
e, coat of moniliform filaments. × 312.

Fig. 11. Showing an adventitious branch. × 375.

Fig. 12. Showing a very young procarpic branch. × 500.

Fig. 13. Young procarpic branch producing branchlets on the convex side. × 500.

Fig. 14. Young procarpic branch, which has become decidedly spirally twisted. × 500.

Fig. 15. Procarpic branch with trichogyne (*tr.*). The branchlets have been mostly removed in crushing. × 500.

Fig. 16. Showing a trichogyne attached obliquely to the pedicel. × 385.

Fig. 17. Trichogyne with antherozoid attached and with trichophore budding. × 385.

Fig. 18. Showing the same points, but farther advanced. × 385.

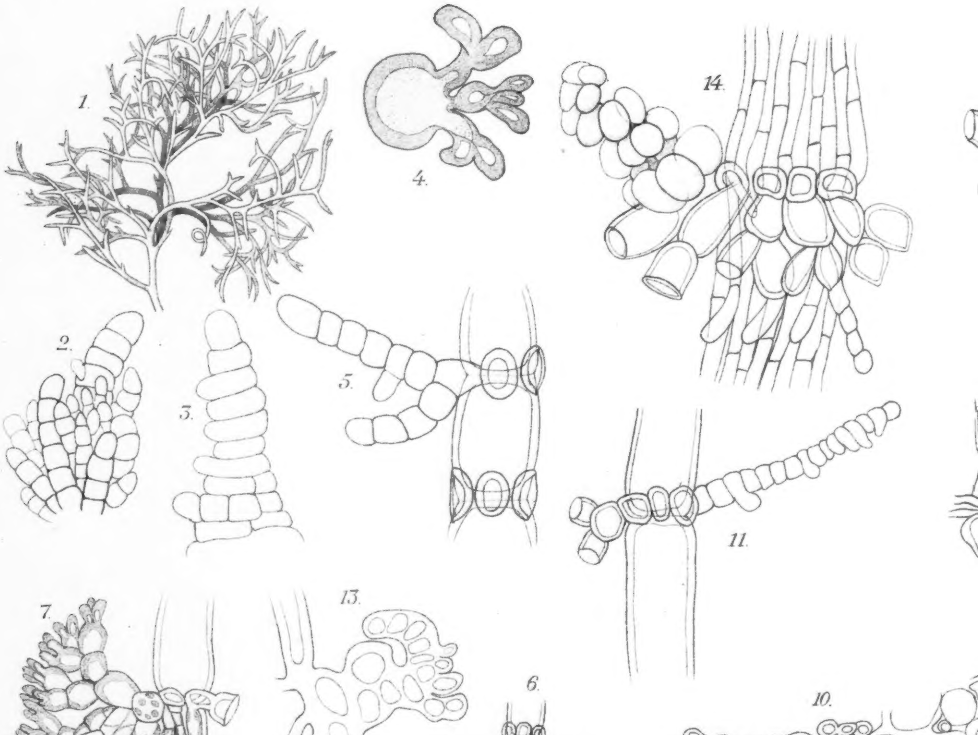
Fig. 19. Trichogyne with two antherozoids attached and with the trichophore budding. × 385.

Fig. 20. Young cystocarp. × 500.

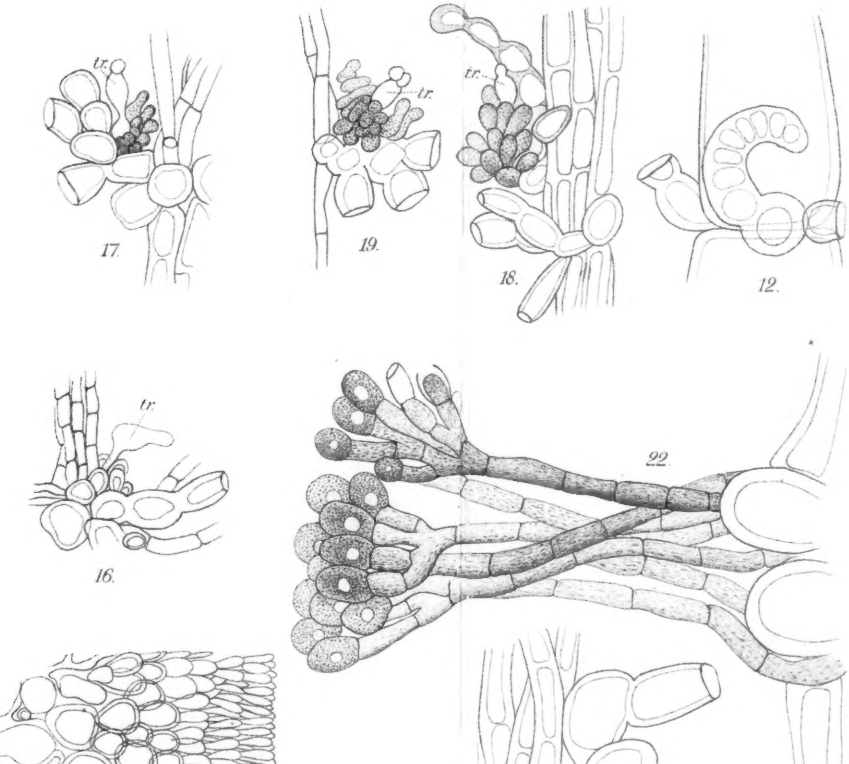
Fig. 21. Extremity of an antheridial branch with antheridia. × 385.

Fig. 22. Portion of a cluster of antheridial branches, seen in longitudinal section. × 500.

Figure 1 was drawn by Mr. William D. Denton from a living plant; the rest of the figures were drawn by the author, with the aid of the camera lucida.



Setchell, del.



B. Meisel, lith. Boston.

V.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XXXV. — ON THE EXTENT OF THE EXCURSION OF THE ELECTRODES OF A MICROPHONE TRANSMITTER.

By Charles R. Cross.

Presented April 9, 1890.

The character and extent of the motions of the electrodes of a microphone transmitter, when actuated by sound-waves of different degrees of intensity, is a subject in telephony of by no means slight importance, but to which very little study has been given. The present paper describes the results of some observations relating to this subject, which have been made at various times during the past two years.

Several years ago an attempt was made by Mr. W. W. Jacques and the writer to gain some knowledge as to the amplitude of the vibrations of the hammer electrode of a microphone, by observing it with a microscope while in operation, and noting the extent of the blurred portion of the image. The results, though giving all that could be expected from so crude a method, were not very satisfactory so far as definite measurement was concerned.

It afterwards occurred to the writer that the matter might be studied more completely by the use of the stroboscopic method, and an arrangement of apparatus was adopted by which the motions of the electrodes could readily be observed.

This was done in the following manner. The microphone to be studied was placed in the field of a microscope, whose line of collimation was horizontal. Behind the microphone, at a suitable distance, was placed a Helmholtz mercury interrupter, with a tuning-fork making 128 vibrations per second. The extra current due to the electromagnets of the interrupter was quite large, so that a brilliant spark was obtained at each rupture of the circuit, as the platinum style of the interrupter left the mercury. The interrupter being properly placed,

and the light of the spark concentrated by a lens, quite a bright field was obtained, against which the electrodes were seen projected, as silhouettes. The light, though intermittent, of course seemed continuous, since the sparks were so numerous. When good definition was obtained, the microphone was set in operation, usually by means of an organ-pipe placed at a convenient and variable distance, and in some experiments by the voice. The pipe was blown by a constant blast, and great uniformity of intensity in the sound was secured. An open C_3 organ-pipe making approximately 256 double vibrations per second was commonly used, its pitch being variable to a moderate extent by shading the mouth or the opening at the top.

So long as the pipe was an exact octave in pitch above the interrupting fork, the electrodes of the microphone as seen with the microscope appeared to be at rest; but if the interval was slightly disturbed, the stroboscopic effect was observed, and the electrodes seemed to move slowly through their complete course. The rate of this apparent vibration was of course dependent upon the deviation of the pipe from exactness in its interval with the fork, and could be varied at will within quite wide limits.

The extent of the motion of the electrodes could be determined by observing the grains of dust which adhered to them, or some definitely marked roughness on their surface. Measurements were made by means of a spider-line micrometer, the wires of which were placed at a convenient distance apart, and the amplitude of the motions of the selected points of reference on the microphone was determined by estimating the relation of their apparent motion to the distance separating the wires of the micrometer. This last distance was frequently varied to diminish the liability to error from a possible bias of the observer towards an agreement with earlier results.

In the experiments described in the present paper, the electrodes were generally so adjusted that the motion of the anvil electrode was too small to be observed. Under these circumstances the observed motion of the hammer electrode, as measured by the micrometer, was the motion of this relatively to the anvil electrode, which is of course the quantity to be determined, rather than the actual excursion of the hammer electrode.

The microphone was placed in circuit with a battery and the primary of an induction coil, whose secondary contained a receiving telephone. With this arrangement the effect on the ear of the electrical variations due to the various values of the excursions of the electrodes could readily be observed. In many cases a second observer was sta-

tioned at the receiving telephone, which was then placed in a separate room.

Magnifying powers were used of from 50 to 1,000 diameters. With the higher powers the use of an objective of short focal length was difficult on account of the small working distance, so that, although even as short a focus as $\frac{1}{10}$ in. was sometimes employed, it was found much preferable to obtain the needed magnification by the use of short focus eye-pieces.

The brilliancy of the electric spark was amply sufficient for illumination of the field, even with the highest magnification employed; a fact which calls attention vividly to the enormous "instantaneous intensity" (so to call it) of that light. Considering the excessively brief duration of the spark and the very small quantity of matter illuminated, it seems unquestionable that the intrinsic brilliancy is far greater than that of the electric arc, a view fully supported by the results of spectroscopic study.

Various forms of microphone were observed, but the general features characterizing the actions studied were common to them all. As the intensity of the sound acting on the microphone was increased by approaching the organ-pipe to the diaphragm, the motion of the hammer electrode, at first absolutely invisible, was seen gradually to increase, until, when the intensity was very great, the motion was excessive, the anvil electrode being violently pushed aside, and the hammer leaving it on its return motion, so that the circuit was broken at every vibration. At the same time bright sparks were seen between the electrodes. To the ear the simultaneous acoustic changes in the sound transmitted were very striking. The sound of the pipe was distinctly audible, and its quality clear, with motions of the hammer electrode far too slight to be observable. As the sound actuating the telephone became louder, and the excursion of the electrode became visible, the quality continued good, the sound transmitted growing louder; and then, as the excursion increased further, the quality gradually changed, shrill false notes made their appearance, and the sound began to grow harsher, until finally, when breaks appeared in the current, the sound was excessively harsh, and entirely devoid of musical quality. Long before this, however, the characteristic quality of the organ-pipe disappeared.

The following tables will illustrate the results obtained. In making many of the measurements I worked in company with Mr. W. W. Jacques, whose observations were always in substantial accord with my own. A large number of observations have also been made, under

my direction, by Messrs. A. W. Jones and F. L. Dame, students in the Laboratory, whose work has been performed with conscientiousness and accuracy.

The microphone used in most of the experiments was one in which the anvil electrode was a "pendulum electrode," suspended by a vertical rod, hinged at the top, and so weighted as to give to it a proper mass. The desired normal pressure could be obtained by sliding the point of suspension laterally so as slightly to incline the supporting rod, and further, by adding a weight so as to exert a proper leverage, if this was desired. The hammer electrode was pointed and carried by the diaphragm, which was of mica. The sounding pipe was gradually removed from or approached toward the microphone. Care was in all cases taken to keep the wind pressure constant. A single Leclanché cell was ordinarily used, though in a few cases a Grénet cell was employed.

In the various tables, the excursions of the electrodes are in all cases given in fractions of an inch. In designating the material of the electrodes, that of the anvil is stated first.

Tables I. to III. show the results obtained when both electrodes were of carbon; Tables IV. and V., when the anvil electrode was of carbon, the hammer of platinum. Tables VI. to VIII. contain results of observations made with a modified form of transmitter, in which the anvil electrode was also somewhat heavier than in the earlier experiments.

TABLE I.

Electrodes, Carbon, Carbon. — *Magnification, 50 diameters.*

Excursion.	Character of Sound
1000×10^{-6} to 700×10^{-6}	Constant breaking and sparks. Electrodes visibly separating.
600×10^{-6}	Constant sparking. Electrodes occasionally seen to separate.
200×10^{-6}	Occasional breaks and sparks.
200×10^{-6}	Scratchy sound, no sparks.
No visible motion.	Sound clear and smooth.

TABLE II.

Electrodes, Carbon, Carbon. — *Magnification, 50 diameters.*

Excursion.	Character of Sound.
1000×10^{-6} to 600×10^{-6}	Constant sparks; electrodes separating.
800×10^{-6} to 200×10^{-6}	Harsh; occasional breaks and sparks.
150×10^{-6}	Scratchy.
No visible motion.	Clear and smooth.

Whenever the excursion of the hammer was greater than 100×10^{-6} the sound was very scratchy and harsh.

TABLE III.

Electrodes, Carbon, Carbon. — *Magnification*, 160 *diameters.*

Excursion.	Character of Sound.
350×10^{-6} to 300×10^{-6}	Loud, noisy, harsh.
250×10^{-6} to 200×10^{-6}	Very scratchy.
120×10^{-6} to 80×10^{-6}	Scratchy, but less than before.
150×10^{-6} to 100×10^{-6}	Scratchy, but with high overtones.

At the lowest amplitude given in Table III. the quality of the sound of the pipe was first heard, but a still less amplitude was necessary for its satisfactory reproduction.

TABLE IV.

Electrodes, Carbon, Platinum. — *Magnification*, 160 *diameters.*

Excursion.	Character of Sound
250×10^{-6}	Constant sparks and breaks.
120×10^{-6}	Scratchy; occasional sparks and breaks.
70×10^{-6}	Raspy.
50×10^{-6}	Quality distinct, but high squealing overtones present.
20×10^{-6}	Quality better; fewer high overtones.
Less than 20×10^{-6}	Quality better; some high overtones still audible.

The pipe had to be carried twice as far away from the transmitter as in last measurement, to a distance of eighteen inches, before the quality became really excellent.

TABLE V.

Electrodes, Carbon, Platinum. — *Magnification*, 150 *diameters.*

Excursion.	Character of Sound.
120×10^{-6}	Very scratchy; occasional sparks.
60×10^{-6}	Squealing, high overtones.
40×10^{-6}	Fair quality; high overtones prominent.
$< 20 \times 10^{-6}$	Good quality; a little rough.
400×10^{-6}	Constant breaking.
60×10^{-6}	Very raspy.
40×10^{-6}	High overtones strong.
20×10^{-6}	Quality good.

TABLE VI.

Electrodes, Carbon, Platinum. — *Magnification*, 700 *diameters*.

Excursion.	Character of Sound.
200×10^{-6}	Rough, but pitch discernible.
80×10^{-6}	Rough, pitch distinct.
30×10^{-6}	Smooth, with high overtones.
30×10^{-6}	" " "
20×10^{-6}	Quality good; some high overtones.
10×10^{-6}	Good quality.
25×10^{-6}	Smooth, with high overtones.
30×10^{-6} to 40×10^{-6}	High overtones prominent.
80×10^{-6}	Harsh and rough.

TABLE VII.

Electrodes, Carbon, Platinum. — *Magnification*, 940 *diameters*.

Excursion.	Character of Sound.
1000×10^{-6} to 800×10^{-6}	Scratchy, with breaks.
100×10^{-6}	Rough, with high overtones.
80×10^{-6}	Wheezy, with high overtones.
40×10^{-6}	Smooth, but with high overtones.
30×10^{-6}	" " "
60×10^{-6}	Rough, with high overtones.
50×10^{-6}	Harsh, with high overtones.
40×10^{-6}	Smoother.
30×10^{-6}	Smoother, with high overtones.
20×10^{-6} to 30×10^{-6}	Good quality, high overtones present.
20×10^{-6}	Good quality.

TABLE VIII.

Electrodes, Carbon, Platinum. — *Magnification*, 940 *diameters*.

Excursion.	Character of Sound.
1000×10^{-6}	Harsh and screamy.
2000×10^{-6}	" "
1000×10^{-6}	High overtones heard; no distinct pitch transmitted.
400×10^{-6}	High strident overtones present.
100×10^{-6}	High overtones still present.
60×10^{-6}	Sound wheezy.
30×10^{-6}	Sound smooth.
20×10^{-6} to 10×10^{-6}	Quality good.

The differences in the effects obtained with a microphone in which both electrodes are of carbon, as compared with one in which one of the electrodes is of platinum, are well known to every one who has

considered the subject. While with the latter it is more easy to produce an actual break of contact between the electrodes than with the former when the sound is increased, on the other hand the quality is much more satisfactorily reproduced, and does not so rapidly disappear on increasing the loudness. These differences were clearly noticed in the observations. Thus for slight excursions of the hammer electrode the quality of the sound with two carbon electrodes was found to be less satisfactory than when the hammer was of platinum, although in the latter case the point of actual breaking of circuit and sparking was usually reached with a less excursion than in the former one. Evidence of these differences appears in the tables just given, and also in those which follow.

It must be observed, that, while the figures given in the tables show what is the maximum amplitude of vibration of the electrodes consistent with the transmission of quality, they entirely fail to indicate the excessive minuteness of the least excursions which are capable of this result. How minute these sometimes are may be inferred from the following observation.

With a microphone having a somewhat heavy anvil electrode, the organ-pipe was gradually moved away from the diaphragm, and the diminishing range of motion of the electrodes noted in the usual manner. When the pipe was at a distance of three inches the motion of the electrodes was too slight to be visible, although this could have been seen readily with the low magnifying power employed if it had been as great as $\frac{1}{20000}$ in. The pipe, still blown with the same loudness, was then carried farther and farther away. At a distance of thirty-six feet, which was the most distant point from the microphone in the room, the sound of the pipe was still distinctly though faintly audible at the receiver placed in circuit with the microphone, and in a distant apartment.

The results shown in the preceding tables give an idea of the phenomena observable with a microphone of the structure employed. Inasmuch as the primary object of the measurements was to obtain some idea of the actual value of the excursion of the electrode, the mass and normal pressure of the electrodes were not particularly considered, except that they were so adjusted as to give good transmission with moderate loudness of the sound actuating the microphone. But it would of course be expected that the numerical value of the relative excursion of the electrodes corresponding to any given character of sound would vary with the mass of the anvil electrode and with the normal pressure between the electrodes. Two separate sets of observations were made to observe the effects of such variations by Messrs.

Jones and Dame. The latter series was somewhat more complete than the former, besides being carried on with better instrumental appliances, and the results hereafter given are taken chiefly from it.

In all experiments of the nature of those under consideration, it is very difficult to get any fixed standard of quality to which to refer such results as the present. Different observers differ to a certain extent in their estimate of the excellence of the quality reproduced. But the point at which the distinctive quality of the transmitted sound disappears is quite well marked, and a very slightly increased vibration of the hammer electrode causes great harshness to result. For this reason, the name "critical point," originally suggested by Mr. Jones, has been given to this limit, and the excursion corresponding to it has been particularly noted, in tests of the varying effects of mass and pressure.

The transmitter used had its anvil electrode suspended like a pendulum, as before. In order to vary the mass without varying the normal pressure, a horizontal wire was suspended beneath the anvil electrode and rigidly attached to it. The middle point of the wire was vertically beneath the point of suspension of the electrode. The masses added consisted of small copper washers weighing 1.1 grams each. By adding two of these whenever the mass was to be increased, and placing one on each side of the middle point of the horizontal wire, the mass of the electrode was increased, while the normal pressure remained substantially constant. In the experiments whose results are contained in Tables IX. to XIII. the normal pressure was exceedingly small, the electrodes always being kept in very light contact. This condition of things was easily secured by a slight adjustment of the position of the washers. A magnification of 280 diameters was usually employed.

The following results were obtained by the mode of procedure just described.

TABLE IX.

ELECTRODES, CARBON, PLATINUM.

Mass in Grams.	Excursion of Hammer at Critical Point.
4.0	12×10^{-6}
8.1	25×10^{-6}
10.3	37×10^{-6}
12.5	50×10^{-6}
14.7	50×10^{-6}
17.0	50×10^{-6}
19.2	50×10^{-6}
21.4	50×10^{-6}

TABLE X.

Electrodes, Carbon, Platinum.

Mass in Grams.	Excursion of Hammer at Critical Point
4.8	12×10^{-6}
5.9	25×10^{-6}
8.1	37×10^{-6}
10.3	37×10^{-6}
12.5	50×10^{-6}
14.7	50×10^{-6}
17.0	50×10^{-6}
19.2	50×10^{-6}
21.4	50×10^{-6}
25.8	50×10^{-6}
4.5	12×10^{-6}
8.7	25×10^{-6}
10.9	37×10^{-6}
13.1	50×10^{-6}
17.5	50×10^{-6}
21.9	50×10^{-6}

TABLE XI.

Electrodes, Carbon, Carbon.

Mass in Grams.	Excursion of Hammer at Critical Point.
8.5	18×10^{-6}
10.7	18×10^{-6}
12.9	25×10^{-6}
15.1	25×10^{-6}
17.3	25×10^{-6}
19.5	37×10^{-6}
21.7	37×10^{-6}
23.9	37×10^{-6}
28.3	37×10^{-6}

TABLE XII.

Electrodes, Carbon, Carbon.

Mass in Grams.	Excursion of Hammer at Critical Point.
5.7	12×10^{-6}
8.7	17×10^{-6}
10.9	25×10^{-6}
13.1	37×10^{-6}
15.3	37×10^{-6}
17.5	37×10^{-6}
19.7	37×10^{-6}

TABLE XII. — *Continued.*

Mass in Grams.	Excursion of Hammer at Critical Point.
5.7	12×10^{-6}
9.1	18×10^{-6}
11.3	37×10^{-6}
15.5	37×10^{-6}
15.7	37×10^{-6}
17.9	37×10^{-6}
20.1	37×10^{-6}

TABLE XIII.

Electrodes, Platinum, Platinum.

Mass in Grams.	Excursion of Hammer at Critical Point.
7.65	12×10^{-6}
9.85	25×10^{-6}
12.05	31×10^{-6}
14.25	37×10^{-6}
16.45	37×10^{-6}
18.65	37×10^{-6}
20.85	37×10^{-6}
7.65	12×10^{-6}
9.85	25×10^{-6}
12.05	37×10^{-6}
14.25	37×10^{-6}
18.65	37×10^{-6}
20.85	37×10^{-6}

An inspection of Tables IX. to XIII. shows that the value of the excursion of the hammer electrode corresponding to the "critical point," and presumably, therefore, the excursion corresponding to any given degree of excellence in the reproduction of quality, at first rises very rapidly as the mass of the anvil electrode is increased, but soon reaches a maximum value, which is not altered by further increase of mass. The rise appears to be less rapid when both electrodes are of carbon than when one or both of them are of platinum, as may be seen by a comparison of the various tables, or, better still, by plotting the results so as to exhibit them graphically by curves. Also, when both electrodes are of carbon or both of platinum, the maximum and permanent excursion at the critical point is considerably less than when the hammer electrode is of platinum and the anvil of carbon, — a fact which goes to explain the well known excellence of a microphone employing these last materials. Further experiment is desirable, however, before fully accepting this explanation. Furthermore, variations in the sur-

face and shape of the electrodes are likely to modify these values to a certain extent. Thus the carbon electrodes used by Mr. Jones gave the results shown in Tables XIV. and XV. The arrangement of the electrodes was as already described, except that the anvil was slightly inclined, and in the second series a weight of bent wire was added to increase the normal pressure by a small amount.

TABLE XIV.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
6.5	36×10^{-6}
8.9	50×10^{-6}
11.3	60×10^{-6}
13.7	60×10^{-6}
16.1	60×10^{-6}
18.5	60×10^{-6}
20.9	60×10^{-6}
23.3	60×10^{-6}
25.7	60×10^{-6}

TABLE XV.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
2.9	20×10^{-6}
5.3	30×10^{-6}
7.7	40×10^{-6}
10.1	55×10^{-6}
12.5	60×10^{-6}
14.9	60×10^{-6}
17.3	60×10^{-6}

In connection with the various preceding tables the following results obtained by Mr. Jones will be of interest.

TABLE XVI.

ELECTRODES, CARBON, PLATINUM.

Series.	Magnification.	Excursion for Good Quality.	Excursion at Critical Point.	Excursion for Breaking.
1	400	16×10^{-6}	60×10^{-6}	80×10^{-6}
2	400	20×10^{-6}	$30\text{–}40 \times 10^{-6}$	60×10^{-6}
3	400	30×10^{-6}	50×10^{-6}	80×10^{-6}
4	350	30×10^{-6}	60×10^{-6}	80×10^{-6}
5	700	40×10^{-6}	60×10^{-6}	80×10^{-6}
6	1000	30×10^{-6}	70×10^{-6}	80×10^{-6}

In series 2 the normal pressure was slightly less than in the others. The excessively high value of 40×10^{-6} at which in series 5 good quality still persisted, is the highest that has been observed. The hammer electrode had been brought to a sharp point just previously.

I have observed, among the four persons who have employed the method under consideration, that each one has apparently his own standard of what constitutes good quality, and usually adheres quite closely to this in different experiments. The observer last cited generally gave somewhat larger values to the excursion for a given degree of excellence of transmission than I noted in my own observations, apparently from this cause.

A further series of measurements was made in order to ascertain what effect was produced by a variation in the normal pressure between the electrodes.

In order to do this, a wire was caused to project backward from the anvil electrode, and small weights were hung upon the end of it. The pendulum electrode with this projecting wire constituted a bent lever whose arms were easily measured, thus enabling the normal pressure due to a given weight to be calculated. It was thus obtained very easily, although the method is subject to the objection that there is a certain variation of the mass of the anvil electrode simultaneously with the variation in pressure. The use of a delicate spring instead of the weight would be preferable, but I have not yet found time to carry through observations by this method. The results reached are shown in Tables XVII. to XIX.

TABLE XVII.

Electrodes, Platinum, Platinum.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.34	8×10^{-6}
0.77	14×10^{-6}
1.20	25×10^{-6}
1.63	37×10^{-6}
2.06	50×10^{-6}
2.50	61×10^{-6}
0.34	10×10^{-6}
0.77	12×10^{-6}
1.20	25×10^{-6}
1.63	37×10^{-6}
2.06	50×10^{-6}
2.50	61×10^{-6}
2.93	61×10^{-6}

TABLE XVIII.

ELECTRODES, CARBON, CARBON.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.297	8×10^{-6}
0.632	12×10^{-6}
0.990	12×10^{-6}
1.288	12×10^{-6}
1.650	25×10^{-6}
2.150	25×10^{-6}
0.272	8×10^{-6}
0.616	25×10^{-6}
0.960	37×10^{-6}
1.304	37×10^{-6}
1.648	37×10^{-6}
1.990	37×10^{-6}

TABLE XIX.

ELECTRODES, CARBON, PLATINUM.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.184	8×10^{-6}
0.288	12×10^{-6}
0.432	12×10^{-6}
0.632	12×10^{-6}
0.990	12×10^{-6}
1.288	12×10^{-6}
1.654	Anvil vibrating.
0.104	$>8 \times 10^{-6}$
0.132	$>8 \times 10^{-6}$
0.153	8×10^{-6}
0.184	8×10^{-6}
0.288	12×10^{-6}
0.632	12×10^{-6}
0.990	12×10^{-6}
0.180	8×10^{-6}
0.395	12×10^{-6}
0.620	12×10^{-6}
0.644	12×10^{-6}
0.149	8×10^{-6}

It appears from these results, that the value of the excursion corresponding to the critical point rises with increase of normal pressure, soon attaining a maximum and constant value. The pressure at which this maximum value was reached was greatest when both electrodes were of platinum, and least when the hammer electrode was of platinum and the anvil of carbon. When both electrodes were of carbon,

the value lay between these two extremes. The unexpected result was also reached that the value of the maximum excursion was much greater when both electrodes were of platinum than when both were of carbon. It was least when the hammer was of platinum and the anvil of carbon.

A series of observations was also made upon the microphone of the Blake transmitter. These presented considerable difficulty on account of the construction of the parts of that instrument, and only a low magnification could be used. Three sets of measurements were taken, the first with a very light normal pressure, the second with the ordinary pressure, and the third with a very heavy pressure. With this microphone in its proper condition, both electrodes moved. It was therefore necessary to subtract the excursion of the anvil electrode from that of the hammer, in order to obtain their relative motion. The results reached are given in Table XX. The total excursion of the hammer electrode, and its motion relative to the anvil, are given as nearly as they could be measured.

TABLE XX.

Blake Transmitter. — Electrodes, Carbon, Platinum.

Total Excursion.	Relative Excursion.	Character of Sound.
	a. *Light Normal Pressure.*	
	$< 25 \times 10^{-6}$	Good quality, very faint.
50×10^{-6}	25×10^{-6}	" " clear.
100×10^{-6}	50×10^{-6}	Overtones strong.
	b. *Medium Normal Pressure.*	
	$< 25 \times 10^{-6}$	Good quality, very faint.
75×10^{-6}	25×10^{-6}	" " clear.
100×10^{-6}	50×10^{-6}	Overtones strong.
	c. *Heavy Normal Pressure.*	
	$< 25 \times 10^{-6}$	Good quality, very faint.
100×10^{-6}	25×10^{-6}	" " clear.
150×10^{-6}	50×10^{-6}	Overtones strong.

These results, although of only approximate exactness, are interesting, as they show one cause of the excellence of the Blake transmitter in practice, in that the mode of support of the electrodes allows of very considerable variations in the absolute motions of both of them without material change in their relative motions.

Rogers Laboratory of Physics,
March, 1890.

VI.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY.

XIII. — NOTES ON ZONARIA VARIEGATA, Lam'x.

By Herbert M. Richards.

Presented by W. G. Farlow, June 11, 1890.

Late in the year 1889 I began working on a quantity of material of various forms of the Dictyotaceæ which Professor W. G. Farlow had kindly placed at my disposal. The specimens had been collected by him in Bermuda during January, 1881, and were in excellent condition for histological study. Among the first forms I examined, in some material of *Zonaria variegata*, Lam'x,* a curious structure attracted my attention, to which no reference could be found in the accessible literature on the subject. A description of this peculiarity and its mode of origin is the subject of the present paper.

At the outset, it will be well to review briefly some of the most important features in the structure of the Dictyotaceæ, which have been described by previous writers. Of the literature on this subject Naegeli's description† is among the earliest; later a paper was published by Cohn,‡ in 1865, which included a description of *Dictyota dichotoma*, Lam'x. In Bornet and Thuret's "Etudes Phycologiques,"§ besides a brief description of the frond of *Dictyota dichotoma*, there are especially important notes on the fructification illustrated by beautiful figures. The latest as well as the most elaborate paper on the group, however, was published by Reinke in 1878.¶ There he

* The reader should consult J. G. Agardh's account of Zonaria in Lunds Univ. Arsskrift, XVII. 120–131, for the relations between this species and its allies.

† Die neuern Algensysteme, Zurich, 1847.

‡ Ueber einige Algen von Helgoland, Leipzig, 1865.

§ Etudes Phycologiques, Paris, 1878; also Thuret, in Ann. Sci. Nat., Sér. III. Vols. XIV. and XVI.

¶ Entwickl. Untersuch., v. d. Dictyotaceen, etc., Nova Acta, Band XL. Part 1, 1878.

described, in considerable detail, the structure and development of certain of the Dictyotaceæ found in the Bay of Naples. In general, it may be said that the Dictyotaceæ are thin, flat, membranaceous, olive-brown algæ, usually very simple in structure, having tetraspores, antheridia, and certain large ovoid bodies termed by Reinke, Hauck, and others oogonia. In the fronds of the various genera of this group two forms of growth may be distinguished; one by means of a single apical cell, of which Dictyota is a type, and another by means of a row of marginal cells of which Padina affords a good example. While at first it would seem that these two methods of growth are widely different, closer examination shows that the growing marginal cells practically represent a row of apical cells.

The apical growth of *Dictyota dichotoma*, from the formation of the first division to the ultimate condition found, was clearly described by Naegeli, and further details were given by Cohn and by Reinke. From the lenticular apical cell a saucer-shaped cell is cut off by the formation of a transverse wall. This latter cell divides into several by the formation of vertical walls, and later each one of the new cells is cut into three parts by walls parallel to the surface of the frond. Thus the three-layered condition of the adult frond is attained, and the subsequent changes consist chiefly of the division of the outer cells into many parts to form a cortex.

Padina, growing as it does in most European waters, has been abundantly studied, and was for this reason cited as an example of the marginal form of growth, but it differs from other Dictyotaceæ in that the edge of the frond is inrolled. The growing cells which form the margin of the frond of *Padina Pavonia*, Lam'x, may roughly be said to be brick-shaped, with their anterior faces rounded, and their longitudinal axes placed at right angles to the margin of the frond. From them, as in the case of the apical cells in *Dictyota dichotoma*, cells are cut off by the formation of transverse walls. These newly formed cells almost immediately divide horizontally into two parts, one of which grows in area, the other in thickness, so that the edge of the frond gradually curls over on itself, until the inrolled condition is attained. For a considerable space the frond is but two layers of cells in thickness, for the third layer, which is formed by the division of the thicker layer parallel to the surface of the frond, does not make its appearance at once. The increase in breadth takes place from the longitudinal division of the marginal cells, an occurrence that is very common in a young, rapidly growing frond. Besides the large, thin, fan-shaped form of the thallus of Padina usually found,

Reinke also distinguished what he terms Rundtriebe and Flachtriebe, which are interesting as showing the close connection of the apical and marginal forms of growth. The Rundtriebe and Flachtriebe resemble each other closely, both having the apical form of growth, differing only in that the former are round, while the latter, as the name implies, are more or less flat. The change from the Flachtriebe to the Breittriebe, as Reinke terms the expanded form of the frond, is accomplished by a change in the mode of growth. Actively growing marginal cells, like those already described, become differentiated from the cells bordering the edges of a Flachtrieb, and the apical cell is obliterated. A very characteristic feature of the expanded form of Padina, and one that should not be passed over, is the hairs which beset both surfaces of the frond. They occur in prominent and regular concentric lines, and are developed from the outgrowth of the superficial cells.

In *Taonia atomaria*, Ag., we have perhaps a more typical form of those genera where the growth is marginal. For a detailed description one should refer to Reinke's paper already alluded to. A few words regarding it will suffice here. In the structure of the frond it differs mainly from Padina in two features; the edge of the frond is not rolled inwards, as in the latter genus, and the hairs, instead of being in definite parallel lines, are in more or less irregular zones. Besides *Taonia atomaria*, Reinke describes another Mediterranean form, with a flat and not incurled margin, which he considers to be *Zonaria parvula*, distinguishing it, however, from the so called *Zonaria parvula* of some older writers, now included in *Aglaozonia reptans*, one of the Cutleriaceæ. The frond of *Z. parvula* is thin, flat, more or less irregularly expanded, and on its under side beset with rhizoid-like hairs, which attach it to the substratum. The growth is by marginal cells, as in Padina, but it resembles Taonia in having the edge of the frond flat. Usually the thallus is but three cells in thickness, consisting of a single-layered, small-celled cortex on each side of the frond, and of a large-celled internal portion. The latter layer, while it is usually only one cell in thickness, may in places become divided into several layers. The growth of the frond from the marginal cells is very much as in Padina, except that both of the cortical layers are formed simultaneously.

The reproductive organs, while they differ considerably in their arrangement in the various genera, are much alike in structure. They are all outgrowths of cortical cells. The development of the tetraspores is as follows. A group of cortical cells becomes considerably

enlarged, taking on at the same time a dark brown color. Basal cells are cut off from these enlarged cells by the formation of walls parallel to the surface of the frond. The upper cells then rapidly become very much larger, and when they have attained their full size their contents divide into four spores, which on escaping may develop into new plants. There may or may not be a cuticular envelope covering the tetrasporic sorus in its young stages. In Dictyota the spores are found strewn irregularly over both sides of the frond. In Padina and Taonia they develop on the upper side in the region of and following the same general course as the trichomes. In Zonaria, again, the arrangement is irregular, but the sori are more compact than in Dictyota. While in a majority of cases the oogonia and antheridia are found on separate fronds, in Padina they occur together. The oogonia develop very much in the manner of the tetraspores, by an enlargement of the cortical cells; their contents, however, do not divide into four, but remain as a single mass. The antheridia differ considerably from the oogonia and tetraspores in their growth; the cortical cells after becoming somewhat elongated lose their color entirely, and then by a series of divisions in three directions are cut into many cells, in which the antherozoids are formed.* In Dictyota, which is one of the diœcious forms, the oogonia and antheridia are found in sori scattered irregularly over both sides of the frond. In Padina they occur in zones situated on each side of the concentric lines of hairs. Of these zones the oogonia constitute by far the greater part, being in large masses separated at irregular intervals by narrow spaces of antheridia. Taonia like Dictyota is diœcious, and the oogonia and antheridia are found as in the latter genus. In Zonaria tetraspores alone are known.

In a few words, then, Zonaria may be distinguished from Padina and Taonia as follows. The absence of the inrolled margin is sufficient to separate it from Padina, while the absence of any distinct bands of hairs and the consequent position of the reproductive organs distinguish it, though not so distinctly, from Taonia. It is true that most species of Zonaria are marked with concentric lines, but the lines are rather zones of growth than bands of trichomes. It is indeed concerning these zones of growth that I propose to speak later, but it will be necessary before discussing them to trace the growth and general histological structure of the frond.

Zonaria variegata, Lam'x,* was the form used in the following investigation, and the material, as I have already said, was collected

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* Thuret, Ann. Sci. Nat., Sér. III. Vols. XIV., XVI.

by Professor Farlow in Bermuda. From dried specimens the frond is seen to be more or less fan-shaped, though not so markedly as in Padina, for it is attached by a broader base. When young the frond is prostrate, being fastened to the substratum by the rhizoid-like hairs on its under surface. As the frond becomes older, however, it is often erect, for the hairs break away except at the base, and few new ones are formed on the growing parts. The adult frond is somewhat rigid, not as much so indeed as that of Padina, for there is no incrustation of calcic carbonate, as in the case of the latter. The surface of the frond is marked with fine striations, running lengthwise along the frond, which can be faintly seen with the naked eye and plainly with a hand lens. Running in the opposite direction one can see, at considerable intervals, very strongly marked concentric lines. In its histological structure, *Z. variegata* resembles *Z. parvula* to a considerable extent, differing mainly in the number of layers of cells of which it is composed. There is a row of the same brick-shaped marginal cells with rounded apices as found in the other species (Fig. 1). These marginal cells are cut into two unequal parts by the formation of a series of transverse walls. The larger and upper ones — if we consider the frond in its erect position — continue their office of enlarging the frond, while the lower ones become merged with the rest of the frond. These lower cells soon divide into three parts, by the formation of two walls parallel to the surface of the frond in each cell, thus making an inner and two outer layers. Later, more cells are cut off from the central layer in the same direction as those first formed, until what may be termed a cortex is formed, which may be from two to four cells in thickness (Fig. 2). It must be borne in mind, however, that while these layers thus formed will, to avoid confusion, be hereafter called the cortex, one cannot well say where the cortical cells end and the medullary cells begin, for as far as the color and character of the contents go there is a gradual transition from one to the other. The color of the contents of the outside layer is dark brown, that of the next somewhat lighter, until in the medullary layer they are almost colorless. The outermost layer not long after its formation divides up by transverse and vertical walls into many small cells. The same division takes place in the next layer to a lesser extent, but the others remain as they were when first formed. Thus in a fully developed portion of the frond, beginning at the inside and going outwards, there is first a large-celled central layer, then from one to two layers of large flat cells, which, with the two outer small-celled layers, may be said to constitute the cortex. In the young thallus the margin is

entire; but it soon becomes split, though to a less degree than in some species of Zonaria. The splitting takes place by a process very like that described by Reinke in the case of *Taonia atomaria.* Usually a small number of the marginal cells die, and their contents disintegrate, forming a brownish structureless mass. Since the marginal cells on either side continue to grow, there is formed a cleft, which gradually grows deeper and deeper, finally forming a split which becomes visible to the naked eye.

It was in a vertical longitudinal section of the frond which I had cut to study the apical growth, that a peculiar appearance like that shown in Figure 2 was seen. This occurred to me at once as strange, and unlike anything I had seen before. No reference to any such condition could be found in the literature on the subject, and, unless I am greatly mistaken, it has never been mentioned. This singular condition when fully formed may be briefly described as an overlapping forward of the cortical cells over the frond. That to this overlapping the appearance of transverse zones is due, becomes evident on viewing it with a low power from above, when the lines of the projecting cortical cells may be seen at more or less regular intervals. These zones should not be confounded with the comparatively fine and indistinct lines which run parallel to them, and are only to be seen on viewing the frond obliquely. The latter markings are apparently due to slight undulations of the cortical cells, while the zones referred to are much more complicated in structure. In a vertical section of the zones in their fully formed condition the most prominent feature are the outgrowths on both sides of one or two layers of the cortical cells. But besides this, it is seen that in the region of the zonal growth the medullary cell has become divided into three or four parts horizontally, and that the whole frond in that place is somewhat thickened (Fig. 2). The earliest stage in the development of these zones that I was able to find in the material at hand was young enough to give pretty clear evidence as to their origin. In this stage the medullary cells in the region of the zone about to be formed became divided into three or four cells by the formation of longitudinal walls parallel to the surface of the frond (Fig. 3, m'). The medullary cells which undergo division in this way form usually a single row parallel to the margin of the frond, but occasionally, instead of a single, they consist of a double row (in Figs. 3 and 4 the direction of the margin of the frond is indicated by the letter A). At the same stage the cortical cells (Fig. 3, c) in the immediate neighborhood of the developing zone can be seen to have undergone a change. The two outermost layers if there are

three or four in the frond, or the single outer one if there are only two, have begun to disintegrate (Fig. 3, c'). These cortical cells have lost their definite shape, the walls between them having undergone a process of absorption. This absorption has not progressed so far, however, that traces of the original outline of the cells cannot still be seen in the stage figured (Fig. 3, *d*). The contents have also much altered, becoming in the process of disintegration a dark brown color. The absorption and degeneration continue, and finally even the outer cell wall is broken away and the now structureless mass of contents escapes as is shown in Figure 4, c'. Other changes have also taken place. The cells composing the layer next inside the disintegrated cortical cells have enlarged somewhat (Fig. 4, *ic*), and on looking at the medullary cells, which in this region it will be remembered have increased in number, it will be seen that their anterior, or marginal, ends have become thicker, so that the cells are more or less wedge-shaped. The frond has thus become so enlarged, that the cells of what I have called the innermost layer of the cortex are so displaced that, while posteriorly (B) they retain their connection with the layer of which they are in reality a part, anteriorly (A) they appear to be continuous with the outer layer of the cortical cells of the younger part (Fig. 4, *ic*). The cortical cells just posterior to the zone of disintegrated cells described have begun to grow forwards, and their course being somewhat divergent they turn outwards, finally forming the overlapping ridges (Fig. 2) which give the zoned appearance to the surface of the frond. The cortical cells do not grow on indefinitely, but usually project only the length of a few cells, sometimes, however, growing farther (Fig. 2). As regards the relative stage of development of these zones on various parts of the frond, it may be said that the early stages are always found near the margin of the frond, and, while fully developed ones are sometimes met with close to the edge (Fig. 2), one must look for the oldest farther back.

The nearest reference that can be found to anything approaching the condition described in this curious overlapping, is in Reinke's description of *Z. parvula*, where he says that not infrequently the middle layer was found to be divided irregularly;* but he does not speak of the formation of zones in this connection, nor does he mention any other of the changes that I have described.

The part which the overlapping takes in the economy of the frond is a point concerning which only conjectures can be made at best. It

* Entwickl. Untersuch., v. d. Dictyotaceen, etc., p. 35, Taf. VI. Fig. 4.

does not seem to be connected in any way with the formation of either the reproductive organs or the hairs. One might suppose that the different zones represent successive periods of growth and rest. For instance, the zonal outgrowths may represent a point where the growth of the marginal cells was checked, and where, after a period of quiescence, they began growing again suddenly. What the cause of such a cessation and subsequent resumption of growth might be, is a question which cannot be decided without carefully observing the conditions of growth of the plant. It is to be regretted that the plant could not have been studied in the living state; but that was of course impossible, owing to the remoteness of its habitat.

Of the hairs in *Zonaria variegata* two kinds may be distinguished, those which occur in tufts scattered irregularly over the frond, and those which are rhizoid-like in their nature, and are found chiefly near the base on the under side of the frond, not arising in compact tufts like the others. The hairs in the tufts are always unbranched, and are composed of long cylindrical cells placed end to end. They develop from the elongation of a group of cortical cells, and are in the young stages protected by a covering which subsequently breaks away, as described by Naegeli in the case of *Padina Pavonia*. The rhizoid-like hairs resemble those which develop in tufts in that they are outgrowths of the cortical cells, but they differ in that they are scattered irregularly over a considerable area. They may also be distinguished by the greater length of their component cells and by the fact that they are branched (Fig. 5). While they are usually developed only near the base of the frond, they may occur to a limited extent anywhere on its under surface.

The reproductive bodies which I found on the frond of *Zonaria variegata*, although no division into four parts was seen, were presumably young tetraspores. As Bornet has remarked,* however, it is very difficult to distinguish the tetraspores from the so called oogonia unless the division of the former into four parts is seen; and although apparently not a difficult matter to detect the four tetraspores in living material, in dried or alcoholic material the mother cell of the tetraspores often appears to be undivided. They arise from the enlargement and division of groups of epidermal cells, and are protected in their young stages by a covering like that found in the case of the hairs. They were not at all definitely arranged, being scattered irregularly in patches between the overlapping zones.

* Etudes Phycologiques.

In examining some material of *Dictyota ciliata* which was collected at the same time and place as that of *Zonaria variegata*, I came across an interesting point regarding the tetraspores to which it seems worth while to call attention. The tetraspores in the material examined were apparently not fully developed, at least no typical division into four was seen. Very often, however, a vertical wall divided the upper cell of the tetraspore in half (Fig. 7), which was presumably preparatory to dividing again at right angles to form the quadripartite condition usually found. But this simple bisection was not the only form of division observed. Frequently irregularly placed walls were found which were not compatible with a division of the spore into four parts. In Figure 8, an extreme case is shown. There are apparently two basal cells, somewhat distorted, and in the tetraspore itself, starting from a central cell are several radial septa which divide the spore into a considerable number of parts. The septa were not always to be reduced to such a definite plan; there were several cases like those shown in Figures 9 and 10, where the divisions were so irregular that no order could be found in their arrangement. The significance of this multiple division could not be explained with only alcoholic material; it was too frequent, at least in the specimens I examined, to be an accident. A study of the living plant would be necessary to determine certainly if these bodies were really tetraspores, and not some form of gemmæ.

In conclusion, I wish to express my great indebtedness to Professor Farlow, not only for the use of his material, but also for his kind assistance throughout the course of my work. To Mr. W. S. Wadsworth I am also obliged for specimens of *Zonaria variegata* sent by him from Bermuda.

Cryptogamic Laboratory,
Harvard University.

EXPLANATION OF FIGURES.

Zonaria variegata.

Fig. 1. Small portion of edge of frond showing marginal cells. Surface view. × 83.

Fig. 2. Vertical section near margin of the frond showing a well developed overlapping zone. × 200.

Fig. 3. Vertical section near margin of frond showing a very young stage in the development of overlapping zone. A indicates the direction of the margin, B indicates the direction of the base.

m, medullary cell.
c, cortical cell.
m′, divided medullary cells.
c′, disintegrating cortical cells.
d, remains of walls of cortical cells. × 350.

Fig. 4. Same as Fig. 3, but older stage.

ic, internal cortical layer, which is here pushed aside. × 350.

Fig. 5. Rhizoid-like hair. × 83.

Dictyota ciliata.

Fig. 6. Undeveloped tetraspore. × 200.

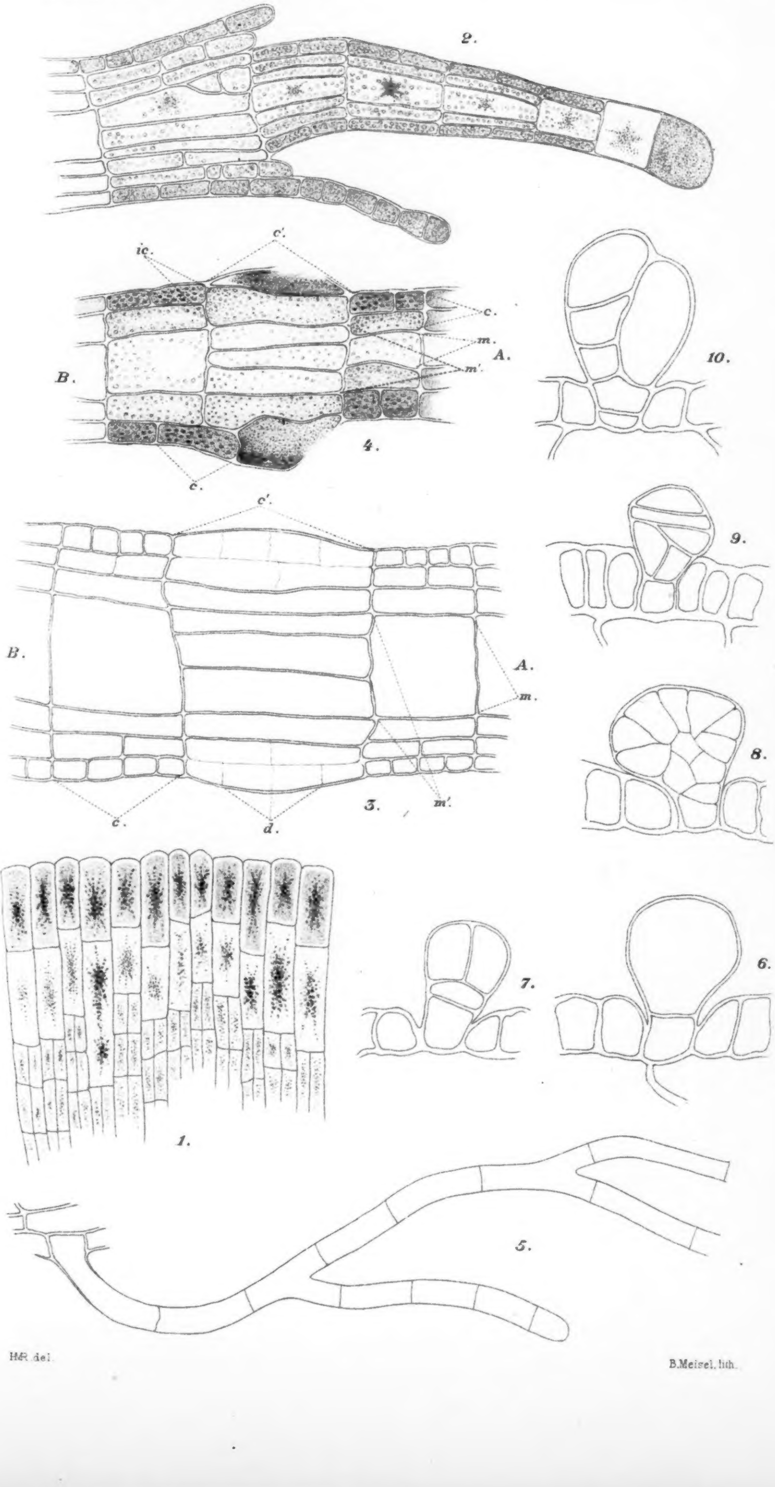
Fig. 7. Tetraspore with two basal cells showing simple bisection. × 200.

Fig. 8. Tetraspore showing radial divisions. × 200.

Figs. 9 and 10. Irregularly divided tetraspores. × 200.

All the figures were drawn with the aid of the camera lucida. From the drawings thus made Figures 3, 4, and 5 were reduced one third; the others remain as they were drawn.

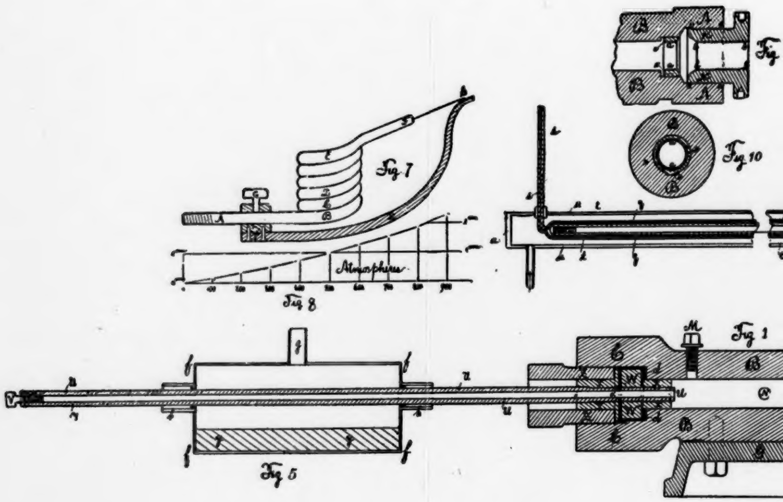
Richards - Zonaria variegata.



H.M.R. del.

B.Meisel, lith.

THE SCREV



Scale 1 i

Fig. 1. — Longitudinal section of the screw compressor, showing the barrel, screw, and lever. Scale $\frac{1}{8}$.

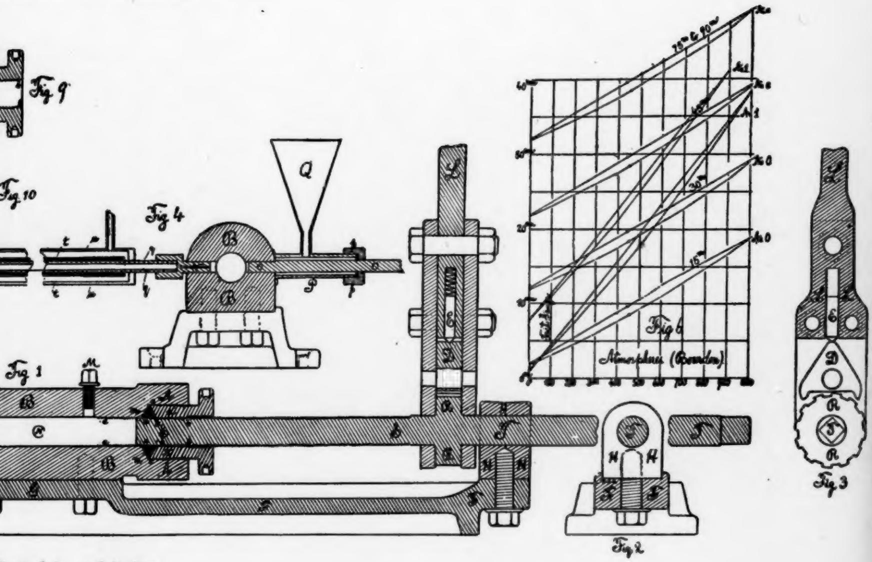
Fig. 2 — End elevation, showing shaft of screw.

Fig. 3. — Longitudinal section of the lever and ratchet wheel. Scale $\frac{1}{6}$.

Fig. 4. — Cross section of the screw compressor, showing the gauge and the oil supply in longitudinal section. Scale $\frac{1}{8}$.

Fig. 5. — Longitudinal section of the piezometer tube and the vapor bath. Scale $\frac{1}{8}$.

SCREW COMPRESSOR.



Scale 1 in = 6 inches.

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ly in

Fig. 6. — Chart showing the bow-shaped cycles obtained in the gauge comparisons.
Fig. 7. — Direct reading, spiral Bourdon gauge. Scale $\frac{1}{6}$.
Fig. 8. — Chart showing the action of the same.
Fig. 9. — Longitudinal section of the improved stuffing box for high pressure compression. Scale $\frac{1}{6}$.
Fig. 10.—Cross section of the barrel showing the ring. Scale $\frac{1}{6}$.

VII.

A METHOD OF OBTAINING AND OF MEASURING VERY HIGH PRESSURES.

By Carl Barus.

Presented June 11, 1890.

1. *Historical.*—Andrews's screw compressor has this advantage, that the acting stress is brought to bear within the compass of the barrel. In other arrangements, such, for instance, in which a cylindrical plunger is forced into the barrel, stress must be exerted against the bedplate, or applied in a way tending to flexure the plunger. The screw compressor may therefore well be taken as the model of an apparatus of greater strength and efficiency than was necessary in Andrews's work. Indeed, Andrews himself seems to have been of this opinion,* and toward the close of his life devised an apparatus of which screw plungers are an essential part. Hannay and Hogarth,† however, were the first to carry the practical improvement of the screw into execution. They reached pressures but slightly short of 900 atmospheres, stating that their reasons for stopping work at this datum were quite apart from the efficiency of their apparatus. With the screw compressor ‡ described below, I obtain above 2,000 atmospheres with facility. §§ 17, 23. It is so constructed that a considerable volume of liquid is operated on, admitting of a compression of five cubic inches of volume decrement. Finally, special provision has been made for the insulation of parts, thus enabling the observer to apply the essential electric methods § in studying his test samples.

Particular notice should here be given of the remarkable modification of Desgoffes's differential manometer, by which Amagat || succeeded

* See Professor Everett's account in Nature, Vol. XXXIX. p. 556, 1889.

† Hannay and Hogarth, Chem. News, Vol. XLI. p. 103, 1880.

‡ It was made for me by the American Tool Co., No. 84 Kingston Street, Boston, Benjamin J. Radford, Superintendent.

§ I here have special reference to Tait's ingenious device. See Proc. Roy. Soc. Ed., Vol. XIII. p. 2, 1884–85. Beiblätter, X. p. 149, 1886.

|| Amagat, C. R., Vol. CIII. p. 429, 1886.

in reaching and of measuring over 3,000 atmospheres. To my knowledge Amagat has as yet given only a meagre account of his machine. Fortunately, however, Professor Tait * recently described the "manomèter a pistons libres" at length, in connection with his own researches. Special comparison of the respective advantages of Amagat's apparatus and the machine of the following papers seems therefore uncalled for.

The Bourdon gauge has been recently discussed by Mr. Worthington † and by Professor Greenhill.‡ The high pressure Bourdon gauge used in my work was of the kind described by the latter.

Screw Compressor.

2. *Disposition.* — The apparatus (Fig. 1) consists essentially of a strong wrought iron barrel, *ABC*, the head of which, *AA*, is suitably threaded, so that a steel screw, *SSTT*, can be forced into it. The piezometer tube is attached at the end, *CC*, of the barrel. Barrel and tubes are quite filled with oil.

3. *Special Devices for preventing Leakage.* — The first of these is the tinned screw. This is an ordinary well cut machine screw of iron or steel, covered with a uniform thin adhesive layer of ordinary solder by dipping it in a vessel of the fused metal. Soldering salts are used in the ordinary way. When forced into their sockets, these screws secure complete freedom from leakage, even at 2,000 atmospheres and more. Gauges and other appurtenances may thus be attached to the barrel, and removed from it with facility.

The other device is the gasket of marine glue,§ or similar very viscous liquid. A stuffing box is easily made, by which this substance is kept pressed against the threads of the screw, or against the smooth surface of a cylindrical plunger. Now whereas the cement admits of being shaped by pressure to fill up any cavity, it is yet far too viscous to flow through capillary interstices, except after the lapse of an enormous time (months). Thus I found the absolute viscosity (g / cm. sec.) to be 200×10^6, that is, about 20 billion times the vis-

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* Tait, Challenger Reports, 1873–76, Physics and Chemistry, Vol. II. See Nature, Vol. XLI. p. 361, 1890.

† Worthington, Nature, Vol. XLI. p. 296, 1890.

‡ Greenhill, Nature, Vol. XLI. p. 517, 1890.

§ Supplied by M. Ducretet of Paris, the Société Génevoise, and doubtless by many others. It is a specially prepared mixture of rubber and shellac. To thicken it, more shellac may be added. Perhaps pitch, or even molasses candy, would be similarly serviceable.

cosity of water. It would therefore require 1,000 atmospheres to force this sample of marine glue through a capillary tube .01 cm. in diameter and 1 cm. long, at the small rate of .05 cm. per hour, supposing (an unfavorable supposition) that its viscosity does not increase under pressure. Pressure moreover tends to close capillary interstices between nut and screw, thus making the apparatus even more efficient at high pressures than at low pressures. At high pressures, finally, a single turn of the screw has a much larger pressure equivalent, for the compressibility of the oil has materially decreased.

4. *Steel Screw.* — To rotate the screw *SSTT* (Figs. 1, 2, 3), it is provided with a lever and ratchet, *LDR*. The ratchet wheel is shown at *RR* (Figs. 1, 3), and is square-cut to correspond with the right and left click, *D*. A pin, *E*, sliding in a socket of the lever, *L*, and actuated by a spring (Fig. 1), enables the observer to adjust the ratchet either for forward or retrograde motion of the screw *ST*. The figure gives a full account of the manner in which the parts of lever and ratchet are put together, and I need only add that the (steel) ratchet wheel *RR* is forged to the shaft *T* of the screw.

The screw *SS* is one inch in diameter with twelve threads to the inch. The shaft *TT* is held in position by a journal, *HHH*, fixed between slides (see Fig. 2), and bolted securely down to the bedplate *FG*.

5. *Barrel. Head.* — The planed front end of the cast iron bedplate *FG*, the part *FF* of which is hollowed out to catch drippings, carries the barrel *BBB*. It is seen in cross-section in Figure 4, and its flat side is firmly secured between the guides of the bedplate, by two bolts (Figs. 1 and 4).

KK is the stuffing screw, being essentially a hollow steel nut of the form shown, and provided with a large flange for screwing it forcibly in place. Both the inner and the outer cylindrical surface of *KK* are threaded with twelve turns to the inch. Moreover the inner thread, *bbbb*, of *KK* is a continuation of the thread *aaaa* in the walls of the barrel. Inasmuch as the thread *cccc* also has twelve turns to the inch, it is clear that the nut *KK* can be forced in or out, no matter what the position of the screw *SS* may be. In practice *cccc* is cut first, and the nut screwed in place. After this the whole thread *bbaaaabb* is cut at one time. The gasket of marine glue (§ 3) is shown at *mm*. It is compressed by *KK*. At high pressures, the friction is sufficient to hold the nut *KK* in place without the need of a lock-nut.

It is seen that after the screw *ST* enters the barrel *BB*, the chief strain is borne by the thread *aaaa*.

6. There is an objection to this form of stuffing box, inasmuch as at very high pressures the threads *aaaa* and *bbbb* tend to act as lock-nuts on each other. To obviate this annoyance I devised the method shown in Figures 9 and 10. Here the thread *aa* is movable, being on the inside of a ring, *rr*, of steel, which fits snugly in a socket of the barrel. The ring *rr*, though capable of moving back and forth, cannot rotate, being prevented by the projection *s*, corresponding to a slot in the barrel. In this way the material in the stuffing box is not forced into the barrel on actuating *KK*. Note that the thread within *KK* is carried quite to the end, and that the inner face of *KK* is bevelled very obliquely, thus allowing the gasket to encircle a greater number of threads of the screw *SS*. The strain is now borne by the thread *bb*. Experiment has shown this to be no disadvantage.

7. *Barrel. Body.*—This is perforated by four or more holes (Fig. 1), about ⅜ inch in diameter, and threaded to admit the tinned machine screws. Two of these, *MM*, are vertical, the other two, *N*, *O* (Fig. 4), horizontal. They are of use in filling the barrel with oil, for attaching gauges and other appurtenances.

8. *Barrel. End with Piezometer Tube.**—These steel tubes, *UUU*, are inserted in such a way as to insulate them electrically from the barrel end *CC*. A screw is cut on the end of *UUU*, fitting into a cast iron flange, *WW*, between two cylindrical jackets, *XX* and *YY*, of hard rubber or ivory. These parts *Y*, *W*, *X*, are screwed to the end of the tube *U*, and the cylinders *Y* and *X* are turned large enough to fit the hole of the barrel and the internal aperture of the steel nut *ZZ* snugly. All space within the head *CC* is filled with marine glue, *dd*. This is easily accomplished by melting the cement into the crevices between *Y* and *W*, *W* and *X*, before putting the piezometer in place. A thick gasket, *dd*, is also inserted. After this the remaining annular space around *W*, through which leakage might occur, is filled by forcing in the nut *ZZ* gradually, and at a temperature not too low.† To

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* Weldless cold drawn steel tubing of any dimension may be obtained from John S. Leng, New York, or of Philip S. Justice, Philadelphia, U. S. A. Both gentlemen are agents of English houses whose address is not known to me.

† The figure is somewhat diagrammatic here to exhibit the parts. In practice I use hard rubber cylinders *XX* and *YY*, and two hard rubber annular disks between *YY* and *WW*, and *WW* and *XX*, respectively. When ready for insertion, the cylinders are screwed against *WW*, so that there are mere films of marine glue left between contiguous planes. Finally, the nut *ZZ* is brought in contact with the flange of *YY* (disk) by pressure. It is in view of the fact that *YY* is pressed radially inward toward the axis of *UU*, as well as outward by pressure, that the arrangement holds so well. Repacking is only rarely neces-

obviate the possible electric contact between *W* and *ZZ*, the hard rubber jacket *Y* is suitably flanged. *XX* is also to be flanged (not shown).

9. *Piezometer Tube and Vapor Bath.* — The outer end of *UUU* is closed by the tinned screw *V*. The substance to be examined is here introduced, usually in glass tubes; but the special devices to be adopted for each special experiment are beyond the scope of the present paper. As a rule, the glass sample tubes are adjusted within the compass of the copper vapor bath *ffff* (Fig. 5), which surrounds the steel tube *UU* eccentrically. The vapor bath is merely a long cylinder of brazed sheet copper, containing the liquid *yy*, to be boiled by heating it with a large burner. Vapors escaping at *g* are condensed (condenser not shown) and run back, thus making the ebullition continuous. A number of baths of this kind are at hand, each containing a substance of suitable boiling point. In order to pass from one temperature to another, it is merely necessary to slip off one vapor bath, *ff*, and slide on another. The copper vessels *ff* are of course surrounded with thick asbestos jackets, and proper provision is made to close up the ends of the end tubes *hh*. As far as temperatures not exceeding 200°, perforated rubber corks are satisfactory. For higher temperatures, *hh* are stuffing boxes containing asbestos wicking tightly appressed. It is preferable to lead off the vapor by a long lateral oblique gas-pipe (not shown) and to use the tubulure *g* for the insertion of the thermocouple * for measuring temperature. A tube or jacket through which cold water circulates must surround the piezometer *UU*, between *ff* and the barrel, and between *ff* and the end screw *V*, otherwise the heat conducted along the tube *UU* will eventually melt both the marine glue and the solder joints. It is for the same reason (heat conduction) that annular vapor baths of the kind described in the Bulletin of the U. S. Geological Survey, No. 54, Chapter II., are not admissible. Heat is conducted along the metallic tube more rapidly than it is supplied, and constancy of temperature cannot be guaranteed nor easily measured. It is essential that the vapor be directly in contact with the piezometer tube. Indeed, when very fine temperature work below 200° is necessary, I use the drum *ff* simply for

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sary. I may add, that as an insulator marine glue is not absolutely perfect, the resistance here being a few hundred thousand ohms. For very fine electrical work some other material may be used.

* Cf. Barus, Bull. U. S. G. S., No. 54, 1889, p. 22; Phil. Mag., Vol. XXIX. p. 141, 1890. A special torsion galvanometer, used for measuring the thermoelectric powers, is to be described elsewhere.

the reception of vapor, leading it in at one end and suitably withdrawing it at the other. Low temperatures are obtained by a jacket of circulating water.

10. *Method of Filling.*—When the screw is in good adjustment, fresh supplies of oil are not frequently necessary. The method of filling is indicated in Figure 4. The steel rod *OO*, threaded and tinned at one end, and provided with a strong cross handle at the other, is enveloped by a brass tube, *P*, surmounted by a funnel-shaped inlet, *Q*. Both *Q* and *P* are kept full of oil, and there is an ordinary stuffing box at *pp*. A spring clamp (not shown), keeps the end of *P* pressed against the side of the barrel *BB*, a suitable leather washer being interposed. To fill the barrel, take off the pressure and screw out *OO*, without removing it from *P*. The oil will then follow the retreating screw *ST*. One of the screws *M* may finally be removed, until the oil exudes; for it is clearly advisable to expel air, which must be considerably reduced in volume before it will sustain high pressure.

Ordinary sperm oil or machine oil of a thickish quality is available for filling the barrel. It has an advantage over water in protecting the screw against rust, and perhaps in keeping the moving parts oiled. Mercury is not available, since it would dissolve the tin coatings on the bolts.

11. *Case for Protection.* — Working as far as 2,000 atmospheres explosions are not infrequent. They occur with slight detonation, scattering thin mists of oil; but there has been nothing of a serious nature. It is well to surround the barrel with a case of two-inch plank, and to provide a barricade beyond the end of the piezometer tube. A suitable tin pan placed underneath the bedplate of the screw is of use in catching oil. After filtering, it may be used over again.

The whole apparatus usually works better after some use than immediately after packing. Indeed, it often happens that a tendency to leak shown at 500 atmospheres quite disappears at 2,000 atmospheres, for the packing is compressed and solidified, and the moving parts oiled.

12. *Vertical Piezometer.* — An adjustment similar to *CC UU*, but smaller in dimensions and ending below in a finely perforated screw, may be attached at *M*. The piezometer is thus fixed in vertical position, and is easily adjusted or withdrawn, while the end of the barrel is available for other purposes. § 23.

M10U

PRESSURE MEASUREMENT.

13. *Tait Gauge.** *Adjustment.* — The gauge is inserted at *N* (Fig. 4), and is shown at *qq*, *tt*, *ss*. The essential part is the steel tube *qq*, closed at one end by a close-fitting tinned bolt, *r*, soldered in place, and connecting at the other end with the cup-shaped junction *N*. It is not advisable to cut a deep thread in the tube *qq*. It may, however, be fastened into *N* by a fine shallow thread and solder; and the deep thread cut in the thick-walled tube of *N*, which is then tinned and screwed into the barrel.

To measure the expansion of *qq* under pressure, it is surrounded by a close-fitting glass tube *tttt*, one end of which is joined to the steel tube *qq* by a layer of marine glue. To do this the tubes *qq* and *tt* are clamped in position vertically, with the open end uppermost. A sheet of thin copper foil is wrapped tightly around the end of *tt*, and fastened with wire so as to project somewhat above it, forming a small annular trough. Marine glue is put into this, and the burner applied cautiously from without. The fused marine glue slowly flows down into the space between the glass tube and steel tube, and the heat is withdrawn when the layer is an inch or two in length. When cold, fusible metal is poured into the copper trough in the space left by the glue. The joint thus formed is not only tight, but reliably rigid.† Space must be left for the elongation of the steel tube.

The other end of the glass tube *tt* communicates with the capillary tube *ss* by which the expansions are measured. In Figure 4 this is shown vertically; but it is expedient to bend it horizontally, parallel and close to the jacket *uu*, to which it is rigidly fastened directly over a suitable millimeter scale. In this way the capillary, though 70 cm. or 80 cm. in length, is protected against injury. I may state, in passing, that pressure on the outside of the tube *tt* appreciably displaces the meniscus in *ss*, an error which must be guarded against. It is well, however, to bring slight and constant air pressure to bear on the meniscus, by attaching a *U*-tube containing mercury to the end of the capillary.

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* The form of steel high pressure gauge based on Hooke's law recommended but not constructed by Professor Tait (*loc. cit.*), is somewhat different from the above. I think my form has the practical advantage of greater simplicity, being essentially a single-walled tube. The method of computation is due to Professor Tait.

† It was my purpose to make the tube *tt* of brass, so that the heat of compression would be more quickly dissipated. But I failed to obtain tubing of the proper bore and strength.

U of M

The shell-like space between steel tube *qq* and glass tube *tt* is filled with a liquid of small coefficient of expansion. I first tried mercury, but found it almost impossible to fill *tt* in such a way as entirely to exclude air. It is clear, in view of the friction of the mercury thread in *ss*, that any trace of air in *tt* will vitiate the experiment. The thermal expansion of colored alcohol is too great. I therefore used water containing a little alcoholic solution of fuchsine. This is introduced through the capillary, by evacuating the tube *tt*. It is necessary to repeat the operation a number of times, and to boil out traces of air. I obtained the requisite constancy of temperature, by surrounding *tt* with a jacket, *uu*, of circulating cold water coming directly from the hydrant. To put the liquid in *ss* at a given fiducial mark, a special adjustment for moving the meniscus suggests itself; but this is an exceedingly difficult device to apply, seeing that there must be a minimum of water in *tt*, and that absolutely tight joints are essential. Hence I raise or lower the meniscus, and color it when faded, by inserting filamentary glass suction tubes into the canal *ss*. There is then little difficulty either in adding more liquid to the thread, or in withdrawing liquid from it. Cf. § 14. The steel tube *qq* should be protected against rust, by nickel-plating it. I found, moreover, that water free from air and containing a little alcohol scarcely attacks steel; for bright surfaces remain bright after many months.

By using a long steel tube the effective length can be more accurately stated, for the length error at the joint *tq* is proportionately decreased. Again, since the expansion corresponding to a given pressure increases in absolute magnitude with the length of *qq*, a wider capillary, *ss*, suffices for measurement when *qq* is long. This facilitates the adjustment for fiducial zero already given.

14. *Tait Gauge. Graduation.* — To accomplish this I compared the gauge with a large Bourdon gauge* reading from 0 to 1,000 atmospheres. § 1. The tube of the latter communicated with the barrel, through one of the screws *M*. This comparison is a check on both instruments, and the statistics are therefore given below in detail. It affords no means of testing the value of the standard atmosphere employed; but since both gauges are based on Hooke's law, and provided with suitable scales of equal parts, the relations are well indicated. In the table, $2\,A_0$, $2\,A_1$, and L denote the internal and the external diameters and the length, respectively, of the steel gauge tube *qq*, Figure 4; $2\,\rho$ is the bore of the capillary tube *ss*.

* Furnished by the Société Genevoise.

MCZ

TABLE I. — COMPARISON OF TAIT GAUGE, NO. 0, AND BOURDON GAUGE.

$A_0 = .27$ cm.; $A_1 = .50$ cm.; $L = 100$ cm.; $\rho = .034$ cm.

TIME = —— GAUGE, Bourdon.	15 m. Tait.	30 m. Tait.	45 m. Tait.	75 m. Tait.	90 m. Tait.
atm.	cm.	cm.	cm.	cm.	cm.
0	1.90	2.10	2.00	2.18	2.16
100	3.58	3.70	3.60	3.85	
200	5.20	5.50	5.35	5.55	
300	7.05	7.25	7.20	7.45	7.30
400	8.70	9.00	8.90	9.10	
500	10.50	10.72	10.70	10.85	
600	*12.50	12.50	12.45	12.55	12.70
700	14.10	14.10	14.10	14.20	
800	15.65	15.70	15.70	15.85	
900	17.22	17.20	17.30	17.45	
1000	18.80	19.00	19.00	19.10	19.20
900	16.62	16.70	16.80	16.80	
800	14.65	14 70	14.63	14.70	
700	12.80	12.80	12.75	12.92	
600	10.95	11.00	11.00	11.12	11.00
500	9.30	9.28	9.23	9.35	
400	7.55	7.55	7.50	7.60	
300	5.95	6.00	6.10	6.15	5.85
200	4 50	4.55	4.60	4.60	
100	3.04	3.12	3.15	3.20	
0	1.74	1.90	1.90	2.00	1.60
Rate in centimeters per atmosphere	.0169	.0171	.0172	.0172	

15. The table contains five series of observations made at the times (minutes) stated. In the first four series, I went up to the maximum (1,000 atm.) and down again gradually, but not slowly. In the last, I operated as fast as the experiment would permit. To determine the degree of accuracy, the rates at the bottom of the table may be consulted. These show that a mean displacement of .0171 cm. of the meniscus takes place in the pressure increasing series, for each atmosphere. Considering data on the same horizontal row, it appears that the differences of reading of the new gauge corresponding to a given reading of the Bourdon gauge are greatest in the region of low pressures. At zero the maximum difference observed is .40 cm., equivalent to an error of 24 atm. Again, comparing the two zero readings of the last column, the difference of reading is .56 cm., corresponding to 33 atm. This, therefore, is a maximum index of the inaccuracy of the new gauge, due to the thermal effects of compres-

* Break in the measurements.

sion, and unreasonably hasty work. To diminish this error further, it is necessary to decrease the bore of the glass tube *tt*, Figure 4, thus making the thermometer feature of the gauge of smaller moment. § 18. In the above apparatus this tube was 1.15 cm. in internal diameter, corresponding, therefore, to a liquid interstratum .07 cm. thick. Clearly, this admits of further reduction. It is also feasible to decrease the strength of the steel tube, making the apparatus more delicate.

16. A second point of view is obtained by comparing the data of the pressure "on" and the pressure "off" phases of the above experiments. For convenience, I have constructed the results of Table I. in the chart, Figure 6. The degree of accordance in the "on" phase is satisfactory, since the errors are not above 10 atm., and the loci, apart from slight circumflexure attributable to the Bourdon mechanism, are straight lines. In the "off" series, this good uniformity is lost, and the data lie on consecutive broken lines. The "off" data do not return in the lines of the "on" data. Indeed, the two curves, "on" and "off," enclose a band the maximum width of which is 1.5 cm., corresponding to 90 atm. The interpretation of this curious and persistent phenomenon is therefore of importance.

17. With this end in view, I again compared the gauges after several months' use. The data are contained in Table II. At least five minutes were allowed per observation. Two complete series are given.

The second part of the table gives some data on the constancy of the zero after very high pressure. The slight shifting of the zero observed (equivalent respectively to 10 and to 5 atmospheres) is due to a mechanical imperfection which I subsequently remedied. Hence the gauge is vouched for within 2,000 atmospheres.

It is seen at once that the mean data of Tables I. and II. are identical. Hence, to account for the apparent hysteresis observed, it is necessary to construct other Tait gauges. I did this with much care.

18. *New Tait Gauges.* — The new gauges are numbered 1 and 4. No. 1 is nearly of the same length as No. 0; No. 4 is considerably shorter. The glass tubes (*tt*, Fig. 4) are as close fitting as practicable, and the capillary of No. 1 is of small bore, to insure special accuracy in reading. Of the many series of observations made, two for No. 1 are given in Table III. Table IV. contains a comparison of Nos. 1 and 4. Five minutes were allowed per observation. The capillary tubes were carefully calibrated. In the second part of

TABLE II. — Comparison of the Bourdon Gauge and the Tait Gauge, No. 0, Four Months later.

Large Bourdon.	First Series. Pressure "on."	First Series. Pressure "off."	Second Series. Pressure "on."	Second Series. Pressure "off."	Factor.	Mean Factor.	High Pressure Tests. Pressure.	High Pressure Tests. Reading.
atm.	cm.	cm.	cm.	cm.	cm./atm.	cm./atm.	atm.	cm.
100	6.40	6.30	6.35	6.20	.01715	.01722	0	4.90
200	8.10	7.95	8.03	7.88	.01725	....	2110	40.93
300	9.87	9.70	9.80	9.60	.01720	....	0	5.10
400	11.57	11.39	11.50	11.32	.01728	....	2160	41.95
500	13.29	13.23	13.20	13.12	....	....	0	5.20

TABLE III. — Comparison of Large Bourdon Gauge with the Tait Gauge No. 1.

$\rho = .0220$ cm.; $L = 100$ cm.; $A_1 = 1$ cm.; $A_0 = .27$ cm.

Large Bourdon.	Pressure "on." No. 1.	Pressure "off." No. 1.	Large Bourdon.	Pressure "on." No. 1.	Pressure "off." No. 1.
atm.	cm.	cm.	atm.	cm.	cm.
0	17.81	17.96	0	5.96	6.21
100	21.30	21.00	100	9.42	9.14
200	25.03	24.31	200	13.17	12.36
300	28.85	27.75	300	17.00	15.74
400	32.63	31.32	400	20.74	19.13
500	36.50	35.12	500	24.60	22.84
600	40.35	39.11	600	28.45	26.75
700	44.05	43.10	700	32.15	30.76
800	47.55	47.12	800	35.78	34.75
900	51.25	51.27	900	39.57	39.00
			1000	43.36	43.40

Table IV. both gauges are standardized by comparison with a small sensitive Bourdon gauge, identical with the large Bourdon gauge. F_1 and F_4 are the factors of the Tait gauges Nos. 1 and 4, thus found.

TABLE IV. — Comparison of Tait Gauges Nos. 1 and 4.

No. 1, $L = 100$ cm.; $A_0 = .27$ cm.; $A_1 = 1$ cm.
No. 4, $L = 58$ cm.; $A_0 = .27$ cm.; $A_1 = 1$ cm.

No. 1.	No. 4.	Small Bourdon.	No. 1.	No. 4.	F_1.	F_4.
cm.	cm.	atm.	cm.	cm.	cm./atm.	cm./atm.
—0.40	12.40	0	—1.30	12.02	3.65	1.63
+8.38	16.45	100	+2.28	13.63	3.69	1.67
18.23	20.85	200	6.00	15.29	3.60	1.67
28.43	25.40	300	9.66	16.97	3.73	1.61
38.36	29.80	300	9.65	16.96	3.69	1.66
50.04	34.91	200	5.90	15.26		
59.93	39.41	100	+2.20	13.62		
63.75	41.25	0	—1.30	12.04		
55.03	37.33					
42.89	32.06					
31.90	27.19					
20.09	21.86					
+9.02	16.78					
—0.55	12.30					

In series of the kind given in Table III., the agreement of observations occupying similar positions in similar series is always very close, the mean difference being only 1.2 atmospheres. Nevertheless, the data of Table III. still show decided hysteresis. (See Fig. 6.) The maximum horizontal distance apart of the "on" and "off" series is about 40 atm. Comparing Tables I., II., and III., therefore, the persistence of the apparent lag phenomenon may therefore be considered proved. I further substantiated this inference by grading the cycles.

19. *Errors involved.* — It is expedient to examine the chief errors involved. The discrepancy in question cannot be due to an imperfect Bourdon mechanism; for in adjusting the pressure at any given value just before observing, the actual pressures must as frequently be incremented as decremented, both in the "on" and the off" series. Again, the liquid adhering to the walls of the capillary of the Tait

gauges would show its largest discrepancy at zero atmospheres following a high pressure. Change of temperature of the water jacket (*uu*, Fig. 4), or change of the water pressure, could not give rise to persistent cyclic curves, but would show itself in a displaced fiducial zero.

I think the clue for the interpretation of the apparent hysteresis is the observation that data of the "on" series lie on straight lines, whereas the locus of the data belonging to the "off" series is curvilinear. The cycles have the form of an archer's bow. Hence, bearing in mind that the liquid in *tt* is being heated by compression of the oil in the gauge during the "on" series, and that, even though gradually parting with its heat increment, it is nevertheless *continually* hotter than the surrounding medium; bearing in mind, moreover, that in the "off" series the water in *tt* is cooled by expansion of the oil in the steel gauge, but that *the water is hotter than the surrounding medium only during the high pressure stages, and colder than the surrounding medium during the low pressure stages* (heat having been continually dissipated), — an explanation of the bow-shaped cycles is suggested. Even my last and best Tait gauges, considered as thermometers, are unfortunately very sensitive instruments, showing displacements of 1 or 2 centimeters per degree Centigrade. In Table IV. the cycles are reduced in width, the distance apart being equivalent to only 17 atmospheres; but the error in question here occurs differentially.

A bow-shaped cycle may also be conceived to result as a viscous phenomenon, if a strain (set) were gradually impressed on the gauges during the "on" series, which strain would then assert itself during the "off" series. Without stopping to examine this consideration, I believe the former explanation more probable.

It follows from the present inquiry as a whole, that, to obtain thoroughly trustworthy data, pressure observations should be recorded during the pressure increasing phase of the work. In most experiments this condition is easily fulfilled, since the pressure datum sought is usually reached from zero. Finally, the steel gauge tube must be made with thinner walls than the above.

20. *Tait Gauge. — Volume Increase measured and computed.* — From the dimensions A_0, A_1, L, and ρ, given in Table I., it follows that the increase of the external volume of the cylindrical steel tube of the gauge is $47 / 10^6$ per unit of external volume, per centimeter of displacement of the thread of the capillary tube *ss* (Fig. 4). This corresponds to a volume increment

$$v / V = .00000080 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

per unit of external volume, per atmosphere.

Tait's expression* modified for the present case is

$$v^1 / V = \Pi A^2_0 (1/k + 1/n) / (A^2_1 - A^2_0) \quad . \quad . \quad . \quad (2)$$

where Π is the internal pressure in atmospheres, and k and n the compressibility and the rigidity respectively of the steel employed. Taking k and n from Everett's tables,† viz., $k = 1.84 \times 10^{12}$ and $n = 8.2 \times 10^{11}$, equation (2) becomes, if $\Pi = 10^6$ dynes,

$$v^1 / V = .00000073 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This result is of the same order as (1). The difference is in large part due to the constants k and n, which Professor Everett doubtless found for high grade tool steel, whereas the above tubes, being made of a low carbon steel (not temperable), are nearer wrought iron in their properties. Beyond this, the absolute gauge atmosphere is not vouched for; nor are the coefficients at the end of Table I., being mean values between zero and 1,000 atmospheres, free from the thermal discrepancy discussed in § 19.

Similar results might be obtained from Tables II. and III.; but as they are not an essential part of the present paper I omit them.

When observations are made for the purpose of measurement, however, equation (2) may clearly be utilized to obtain serviceable values of $(1/k + 1/n)$. For instance, A_0 may be accurately found by filling the tube with mercury in vacuo, and weighing. From the known density of the steel tube and its weight when empty, A_1 may then be computed. Similarly ρ is capable of accurate measurement. Therefore by combining (1) and (2), $(1/k + 1/n)$ is measurable with the same degree of accuracy with which Π is known.

21. *Digression. Direct Reading (spiral) Bourdon Gauge.* — Endeavoring to achieve this result I multiplied the number of coils, making a helix of five turns as shown in Figure 7. The spires *B*, *C*, *D*, *E*, *F*, do not touch one another. The end *F* is provided with a needle *FS*, moving over a millimeter scale *S*, supported by a firm arm *TRS*. The end *A* is screwed directly into the barrel. The tube was originally 1 cm. in external diameter and 0.5 cm. in bore. It was flattened parallel to the axis by hammering at red heat, and coiled hot. The internal diameter of the cold helix was somewhat larger than 4 cm., and the upper spire, with its index, extended about a decimeter beyond the helix. The following little table gives the results of a comparissn with the Bourdon gauge.

* Tait, Challenger Reports, Vol. II., 1882, Appendix A, p. 26.

† Everett, Units and Phys. Constants, Macmillan, 1879, p. 53. The data are due to Professor Everett's researches, I believe.

TABLE V. — Comparison of the Spiral Gauge with the Bourdon Gauge.

Bourdon.	Spiral.	Bourdon.	Spiral.
atm.	cm.	atm.	cm.
0	0.00	600	1.28
100	0.17	700	1.55
200	0.35	800	1.87
300	0.54	900	2.30
400	0.76	1000	Explosion
500	1.00	0	1.16

Figure 8, which exhibits these data graphically, shows that between zero and 300 atm. the permanent set is not appreciable. When the pressure is taken off, the fiducial zero reappears, Above 300 atm., permanent set becomes very marked. The helix was ruptured at 1,000 atm. Connecting the final zero (after rupture) with the point for 900 atm., a line is obtained more nearly parallel to the line between zero and 300 atm. The mean motion of the index was, therefore, .0017 cm. per atm. Since high pressure measurement is only contemplated, the gauge would have been serviceable except for the occurrence of permanent set. The cause of this insuperable difficulty is the forging necessary to flatten and bend it, for the drawn resilience of the tube is thus destroyed.* Clearly, a cold bent tube might be used without flattening by suitably attaching a mirror index; but this complicates the gauge, and, owing to the great difficulty of working steel, I abandoned further attempts.

22. *Concluding Remarks.* — Instead of having the screw enter the barrel, good results must also be obtainable by forcing a cylindrical shaft into the barrel. The device shown within *CC*, Figure 1, proves that the gasket of marine glue is quite as serviceable for smooth cylinders as for screws. In case of a cylindrical plunger, however, the strain encountered in forcing the plunger home would be brought to bear on the bedplate. Supposing the general disposition to be retained, this would make the apparatus more cumbersome; for specially strong devices would have to be resorted to in bolting down the barrel, etc. Indeed, I mentioned it as an advantage of Andrews's screw, that

* To make the steel Bourdon, it would be necessary to draw flat steel tubes.

the chief stresses exist within the compass of the barrel. I may state, that it was my original object to obviate the necessity of stuffing boxes altogether, by using a *tinned* screw *ST*. The maximum pressure thus obtainable probably exceeds the limit of the above screw compressor. The tinned screw would have a disadvantage in needing to be freshly coated when it became necessary to refill the barrel with oil. Inasmuch, however, as stuffing boxes are thus quite obviated, and as the screw necessary can be cut by very ordinary means in the laboratory, this serviceable device may well be noted.

23. Finally, I observe that, *cœteris paribus*, the labor necessary in producing the above pressures decreases nearly as the fourth power of the diameter of the screw; for friction and leverage both increase as the radius, and the resisting pressure as the square of the radius. Similar advantage is gained by increasing the number of threads to the inch. Hence, by supposing the initial pressures to be produced by a thick screw (diameter one inch, say) at one end of the barrel, and the final pressures (above 2,000 atm., when the enclosed liquids have become much more incompressible) produced by a thinner screw (diameter half an inch, say,) at the other end of the barrel, the practical efficiency of the screw compressor would be increased. In such a case, the piezometer tube must be vertical. § 12. However, in limiting my present work to 2,000 atm., I have by no means exhausted the power of the above machine. My purpose in doing so was to avoid straining the gauges. I add, in concluding, that among the facilities of the above screw compressor is the almost micrometric accuracy with which pressure can be raised to and maintained at a given value for any reasonable length of time.

VIII.

ELECTRICAL OSCILLATIONS IN AIR.

By John Trowbridge and W. C. Sabine.

Presented May 28, 1890.

The experiments of Hertz on electrical waves have opened a wide field for investigations in electro-magnetism. The qualitative results of Henry and of Feddersen have been expressed in a quantitative manner by Sir William Thomson. Hertz, collecting together the results of previous observers, and reasoning upon the factors in the formula of Sir W. Thomson, — which expresses a relation between the capacity of a Leyden jar and the self-induction of the circuit through which this jar is discharged, — has detected wave motion with its nodal points and ventral segments, on a wire over which electrical oscillations take place.

Hertz has also pointed out that the experimental results confirm Maxwell's theory, that light and heat are electromagnetic phenomena, and that all energy comes to us from the sun in electrical pulsations.

There can be no question of the phenomena of so-called resonance discovered by Hertz. Roughly speaking, the results obtained by Hertz's resonators satisfy the formula, $t = 2\pi \sqrt{LC}$. In which t is the period of the electrical oscillations, L is the inductance of the circuit, and C is the capacity of the jar, or that of the terminals between which the electrical discharge takes place.

Professor J. J. Thomson has based a method of measuring the capacities of dielectrics upon this formula and upon Hertz's work.*

The researches of Feddersen upon electrical oscillations † were more quantitative than those of Joseph Henry; and Lorenz,‡ by his repetition of Feddersen's results, and by his mathematical analysis

* Proceedings of the Royal Society, June 20, 1889.

† Poggendorff's Annalen, Vol. CIII. p. 69, 1858; Vol. CVIII. p. 497, 1859; Vol. CXII. p 452, 1861; Vol. CXIII. p. 437, 1861; Vol. CXV. p. 336, 1862; Vol CXVI. p. 132, 1862.

‡ Wiedemann's Ann., Vol. VII p. 161, 1879.

of them, apparently gave subsequent observers a solid basis for calculation.

The results of Feddersen and of Lorenz were obtained by photography. An image of the electric spark drawn out by means of a revolving mirror was photographed, and the distances between the successive oscillations, shown by dark bands on the photograph, were measured. Lorenz assumed the ratio between the electrostatic units and the electromagnetic units, $v = 300 \times 10^6$ m., as that of the velocity of light; and by means of the formula $t = \frac{2\pi}{v} \sqrt{LC}$ obtained a satisfactory agreement between the result of experiment and the theory. He showed, apparently, that a certain lack of agreement between theory and experiment, which Feddersen had noticed, was due to taking the dielectric constant of glass too small.

It will be noticed that the method of Feddersen, by means of which the electrical oscillations are photographed, apparently affords an accurate method of determining v. For the factors L and C occur under the square root, and the percentage errors of determination of L and C, being under the square, are halved. Lorenz did not repeat the entire work of Feddersen, but only obtained a sufficient number of photographs — taken under definite conditions in regard to capacity and inductance of the circuit — in order to measure t, the time of oscillation. The accuracy of the results which can be obtained for v depends upon the limits of accuracy of the measurements of the photographs, and of the determinations of the dielectric capacity for oscillatory charges.

In reasoning upon the mode of electrical oscillations in dielectrics, it occurred to us that the medium of the dielectric must greatly influence the result. At the instant the electrical oscillations occur, the glass of the Leyden jar is subjected to a strain which is more or less periodic. It is not probable that the capacity of a condenser is the same for rapid charges and discharges as for slow ones, and the measurements of capacity by the ordinary slow methods form no criterion of the capacity of glass under electrical influences which last but three millionths of a second. We therefore concluded to employ an air condenser instead of one of glass, in order to detect, if possible, the effect of the medium of the dielectric upon electrical oscillations. In order to obtain sufficient capacity for a suitable spark, we were obliged to use the cylindrical form of condenser. The first condenser we employed was made of sheet zinc, and consisted of nineteen coaxal cylinders. The inner cylinder had a diameter of 15.1 cm., and the outer,

one of 60.4; the height of the cylinders was 92 cm. The capacity was computed from the formula

$$C = \frac{1}{2} \frac{l}{\log \frac{b}{a}};$$

in which l is the height, and b and a are radii.

A correction for the ends was made as follows. The radius of curvature of the boundary of the cylindrical plates was considered so large in comparison with the distance between them that the boundary was treated approximately as a straight line. We may consider that each zinc cylinder constituted a plate between infinite imaginary planes which were at zero potential, these planes being equipotential surfaces. The zinc cylinder was supposed to have its area extended by a strip of uniform breadth around its boundary, and the surface density was assumed to be the same on the extended plate as on the parts not near the boundary. Following Maxwell (Vol. I. § 196), we have

$\frac{B}{\pi} \log_\epsilon 2 \cos \frac{\pi \beta}{B}$ for the correction for length.

$B = a - b =$ distance between cylinders.

$\beta =$ thickness of cylinder.

$l =$ height of cylinder.

This air condenser was connected with a circuit of parallel wires, which was carefully strung by means of silk thread through the centre of a large unoccupied room. The length of this circuit was about fifty feet. It returned upon itself to the sparking terminal of the air condenser. The jar was charged by a Holtz machine, which worked fairly well under all conditions of the atmosphere. The revolving mirror was a plane one, 4×5 inches, silvered upon the front face. It revolved upon a horizontal axis with an average speed of three thousand revolutions per minute. The frame which carried the mirror bore also a brass arm provided with a minute brush, which rubbed upon a brass sector let into a large disk of ebonite. When the brush rested upon this brass disk, the electrical charge could pass to two terminals of tin, between which the discharge took place. A concave silvered glass mirror, of 313 cm. radius and 16.5 cm. aperture, placed at a distance of 230 cm. from the spark, received the image of the spark and reflected it back to the revolving mirror. From the revolving mirror the image was reflected to a photographic plate, which was at a distance of 259.7 cm. from the rotating mirror.

The adoption of a plane revolving mirror, and a stationary concave mirror of long focus, enabled us to place the photographic plate at a

distance from the revolving apparatus, and therefore to employ less speed for the revolving mirror. There was no sensible aberration of the image. Great care was taken to balance the mirror. Its large size and weight made it very important, on account of the danger of the apparatus flying apart, that it should revolve with uniformity. The axis of the mirror was placed horizontally. This precaution proved to be a wise one, for twice during the course of the many runs which were made the mirror flew into pieces; the excursions of the fragments, however, were confined to a vertical plane. This liability to accident is perhaps inherent in a method which employs a large plane mirror. The increased amount of light which results from the use of a large mirror, however, forms a valuable compensation. The revolving mirror was driven by a gas engine.

In order to determine the speed of the mirror at the instant the spark passed, the following apparatus was devised. The same shaft which carried the revolving mirror also carried a brass cylinder of 5 cm. in diameter and 21 cm. long. This cylinder was covered at each trial with paper which was coated with lampblack. A stylus moving along a stationary rod beside the shaft could be made to draw a spiral upon the revolving cylinder. One terminal of a Ruhmkorf coil was connected with the brass cylinder, and the other with the stylus. A second pendulum was made to break the circuit of the primary of the Ruhmkorf coil at intervals of one second, and at the middle point of its swing. When the stylus was drawn along the stationary rod which served to guide it, it was made to release automatically at the beginning of the second another pendulum held up by an electro-magnet. This latter pendulum, at the middle of its swing, discharged the air condenser through the inductance circuit at the instant that the mirror was in a suitable position to reflect the image of the electric spark into the photographic camera. While the stylus was being drawn upon the revolving cylinder, the spark from the Ruhmkorf coil left its trace upon the blackened paper. The record on the chronograph consisted of a strongly marked spiral line of over fifty turns. The two sparks from the Ruhmkorf coil left their trace upon the blackened paper or spires, which therefore measured the number of revolutions of the cylinder between the swings of the pendulum, and thus gave the rate at which the mirror was revolving. The chronograph record enabled us to measure the time to $\frac{1}{500}$ of a second.

In any operation which requires that an electrical spark should make a record upon a disk or cylinder revolving at great speed, a large Ruhmkorf coil and a strong battery are necessary, especially

if the primary circuit of the Ruhmkorf coil is broken by a pendulum. With the ordinary automatic break, such as is commonly employed upon induction coils, the failure of a single break is unimportant. If, however, a single break fails when a pendulum break is employed, the record of the experiment is an imperfect one. An excess of battery power and a large battery are therefore necessary. A metallic break-piece, also, was found to be more inconstant for our purposes than a mercury break.

It was found that a certain simplicity of contrivance was necessary in the method of discharging the air condenser through the inductance circuit. No arm connected with the revolving mirror could be trusted to break or make an electrical circuit by throwing in or out any form of switch. The great speed at which it revolved broke all arrangements which were tried. By placing a short stiff brush of minute size upon the end of the flying terminal connected with the revolving mirror, and allowing this brush to rub against a brass plate set in an ebonite circle of 41 cm. in diameter, constancy of action was secured.

In order to obtain the same difference of potential at each run, experiments were first made with various forms of unit jars and pith ball electrometers. These devices were speedily given up in favor of a simple balance electrometer. One of the pans of a delicate balance was replaced by a metallic disk. A similar disk, which was stationary, was placed immediately below the movable one. By properly weighting the remaining balance pan, great delicacy and range of indication were obtained. This apparatus constitutes, in fact, an absolute electrometer. A suitable guard ring can be placed around the movable disk.

When the air condenser had been charged to a definite potential, the movable disk of the electrometer closed an electrical circuit in which was included an electrical bell. The observer stationed at the chronograph, at the instant he heard the bell, drew the carriage connected with the stylus along the guides which kept the stylus on the blackened cylinder.

Calling L the coefficient of self-induction, we have

$$\frac{L}{l} = 2 \log \frac{b^2}{a^2} + 1,*$$

in which l is the length of conductors contained between two parallel planes; b, the distance apart of the conductors; a, the radius of wires.

In our case the effect of the ends was found to be inappreciable. The induction due to the ends can be calculated by the repeated em-

* Maxwell, § 685, Vol. II.

ployment of the formulas for geometric mean distance * for two lines whose directions intersect at right angles.

Lord Rayleigh has given the following formula for inductance under rapid oscillations : —

$$L' = l\left(A + \sqrt{\frac{\mu R}{2 \rho l}}\right);$$

in which A is a constant, depending on form of circuit; μ is permeability; R is resistance; $\rho = \frac{2\pi}{t}$, where t is time of oscillation; l is length to and fro of inductance circuit.

The final value of L' for our case is $L' = 39697$.

The radius of the wire employed was $a = .0501$ cm.

The length was measured in three sections : —

No. 1,	length 1197.0 cm.	distance between wires	$b_1 = 31.55$ cm.
No. 2,	" 281.0	" " "	$b_2 = 16.1$ cm.
No. 3,	" 103.0	" " "	$b_3 = 11.3$ cm.

The ohmic resistance of the wires was $.742 \times 10^9$ for direct current, and 1.54×10^9 for alternating currents of period $t = .0000031$.

The difficulty in the process of photographing the spark consisted in discharging the air condenser through the induction circuit at the instant the revolving mirror was in a position to reflect the image of the spark to the photographic plate. The terminal connected with the revolving mirror, which allowed the electrical discharge to pass when the mirror was in the desired position, had to be adjusted with extreme care. The speed of the image at the photographic plate was about one mile per second.

The photographs were measured by means of a dividing engine. At first an objective of low power was used on the microscope of the dividing engine. It was found, however, that a simple cross hair, unaided by a lens, moving directly against the negative, was better than any eyepiece. Measurements were made of the intervals between the electrical oscillations at both terminals.

In later experiments a smaller air condenser was employed, for reasons which will appear in the conclusions of our paper.

A summary of the details and dimensions employed is given herewith.

Small Air Condenser (No. 2), cylindrical.

19 zinc cylinders.

Height, 30.47 cm.

Diameter of inner cylinder, 7.60 cm.

Diameter of outer cylinder, 25.95 cm.

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* Maxwell, § 692, Vol. II.

Average distance apart, .5 cm.

Capacity (geometric) 5317.9 absolute units, — corrected for the capacity of ends.

Capacity of wire, 200.

Self-induction, in three sections, radius, .0501.

1. Length, 1197.
   Distance apart of parallel wires, 31.55.
2. Length, 281.
   Distance apart, 16.10.
3. Length, 103.
   Distance apart, 11.3.

For alternations of slow period.
  Ohmic resistance, .742.
  Self-induction, 41090.
  Theoretical time with these values, .00000310 sec.

For alterations of period, .00000310 sec.
  Ohmic resistance, 1.54.
  Self-induction, 39700.
  Theoretical time, 00000304.

Distance from spark to concave mirror, 230 cm.

Distance from rotating mirror to negative, 259.7 cm.

Sparking distance, .23 cm.

The following is a sample record (see Figures 5 and 6). Each negative was measured three or more times, and the mean taken. The lengths are given in centimeters. The last line is the time in millionths of a second.

RIGHT TERMINAL.

.289	.541	.561	.598	.552	.511	.544	.560	....
.295	.528	.560	.595	.542	.542	.550	.585	.492
.290	.528	.582	.602	.518	.538	.550	.570	.532
.292	.518	.585	.592	.540	....	....	....	....
.291	.529	.572	.597	.540	.528	.549	.572	.512
1.65	3.00	3.24	3.38	3.06	3.00	3.11	3.24	2.90

LEFT TERMINAL.

.461	.611	.582	.522	.508	.551	.554
.464	.609	.567	.543	.500	.585	.556
.462	.607	.574	.532	.502	.570	.542
.462	.609	.574	.532	.503	.569	.551
2.62	3.45	3.25	3.01	2.85	3.22	3.12

Number of revolutions per second, 54.06.

Length of spark, .23 cm.

The discharge of a glass Leyden jar gave the following values, when reduced to seconds, different lengths of spark being used.

Length of Spark.	Terminal.	Time of Successive Oscillations.					
.4 cm.	Right	1.66	3.22	3.30	3.44	....	....
	Left	3.33	3.37	3.30	3.36	....	....
1.3 "	Right	1.71	3.32	3.45	3.37	3.42	....
	Left	3 30	3.43	3.42	3.43	3.42	3.50

Figure 7 shows that the length of the spark exerts an inappreciable effect.

The following table gives the values in millionths of a second of the successive oscillations on six negatives taken with small air condenser under the conditions given on the preceding page. The first on the right terminal is a half-oscillation. The rest are double oscillations.

RIGHT TERMINAL.

1.65	3.00	3.24	3.38	3.06	2.91	3.11	3.24	2.90
1.68	3.22	2.99	3.35	3.03	2.97	....	....	....
1.90	3.11	3.01	3.31	3.00	3.29	....	....	....
1.95	2.95	3.00	3.08	3.06	3.20	3.03	3.03	3.16
1.62	3.01	3.34	3.04	....	....	....	....	....
1.64	3.18	3.14	3.18	3.03	....	....	....	....
1.74	3.08	3.12	3.22	3.04	3.09	3.07	3.13	3.03

LEFT TERMINAL.

2.62	3.45	3.25	3.01	2.85	3.22	3.12	....	....
2.89	3.50	3.08	3.21	....	....	....	....	....
3.11	3.12	3.30	2.96	3.35	3.39	3.16	3.06	....
2.75	3.63	3.02	2.97	3.48	3.22	3.00	3.18	3.19
2.84	3.19	3.36	2.89	3.41	3.00	....	....	....
2.88	3.19	3.13	2.90	2.96	....	....	....	....
2.85	3.39	3.19	2.99	3.21	3.21	3.09	3.12	3.19

The values for the different negatives are plotted in Figures 1, 2; the mean values, in Figures 3, 4. The time of the first half-oscillation was doubled in plotting. On each ordinate is plotted the time of one oscillation, — on the first ordinate the time of the first oscillation, on the second the time of the second. It should be noted that the curved lines are meaningless, except where they cross the vertical ordinates, serving merely to connect the points belonging to one negative.

The difference in the time of oscillations cannot be explained by the vibration of the discharging arm lengthening and shortening the sparking distance, since this would necessitate a vibration frequency of 100,000 per second, and an amplitude of at least one millimeter; a velocity and momentum impossible for the apparatus either to acquire

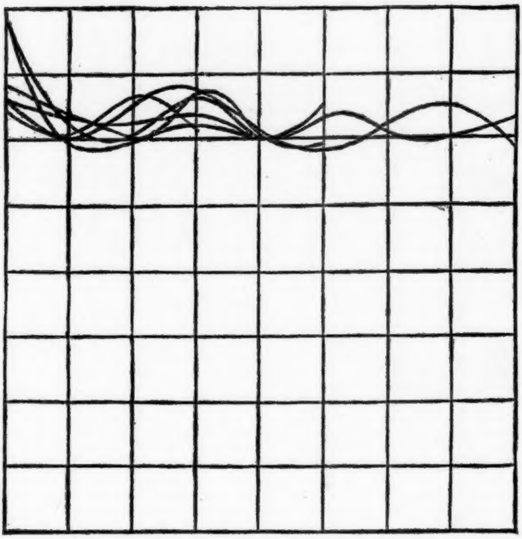

FIG. 1.

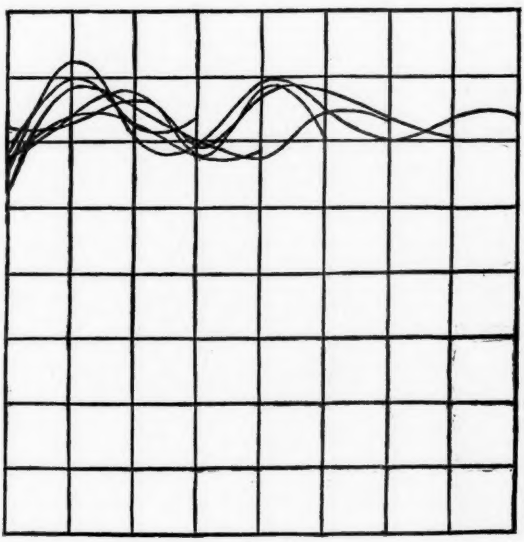

FIG. 2.

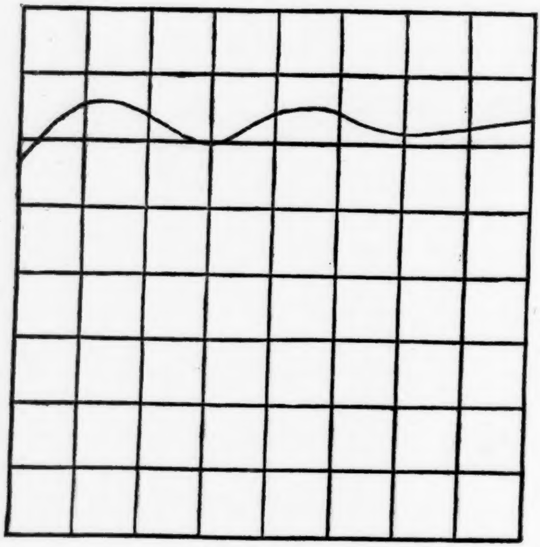

FIG. 3.

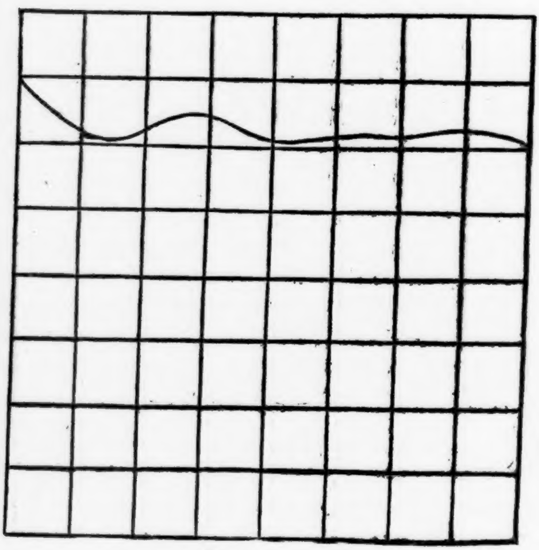

FIG. 4.

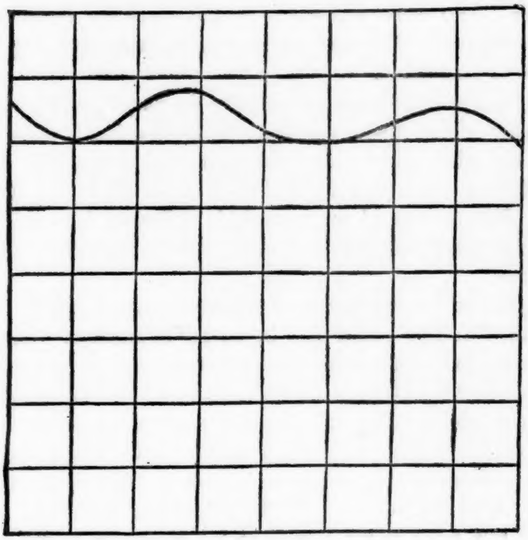

FIG. 5.

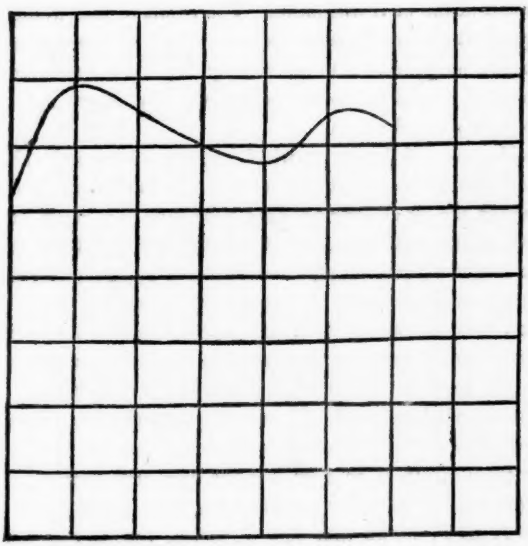

FIG. 6.

or endure. This cause also would tend to make the variation range equally above and below the calculated value as the sparking distance increased or diminished.

Another explanation may be sought in the varying ohmic resistance of the path of the spark, although this explanation is inadequate to explain the whole effect. In order to test it, a long (1.3 cm.) and short (.4 cm.) spark were taken from a glass Leyden jar (see Figure 7). Not only could no appreciable difference between the two plates be detected, but there was no variation in the time of successive oscillations.

In regard to the measurement of the negatives on the dividing engine, the following points may be worthy of mention. At the time the measurements were made, it was expected that the sparks from the glass condenser would show the variations, and that the air condenser would give the constant and theoretical period of oscillation. The reverse of this appeared when the results of the measurements were reduced. Moreover, the measurements were made by a run of the dividing engine from one end of the negative to the other; so that if an error was made in the setting of the cross-hair on the image of one discharge, — for example, making the measurement of that oscillation large, — a corresponding amount would be deducted from the measurement of the next oscillation. The result of this would be, that if the apparent variations were due to errors in measurement, the periods of discharge would be alternately large and small, or at least as often and as far below the theoretical value as above it. But this is conspicuously not the case.

A consideration of the curves which represent our results shows that with quick oscillations which result from the employment of a small air condenser, the air dielectric did not have time to recover completely, in the time of one oscillation, from the strain to which it was subjected. With the larger air condenser, the oscillations being slower, more time was given for this recovery, and hence the periodicity which we have discovered was not so marked. It seems, therefore, that not only should an electrical resonator be turned for capacity and self-induction, but also for a certain periodicity of strain in the dielectric.

In the case of glass, we should not expect to obtain evidence of this periodical recovery from a quick strain, since it is well known that the recovery from strain is so slow that the discharge from a Leyden jar is incomplete after a discharge lasting a second. The curve we give for glass (Fig. 7) shows that this periodical recovery is too slow to manifest itself during the time of quick oscillation.

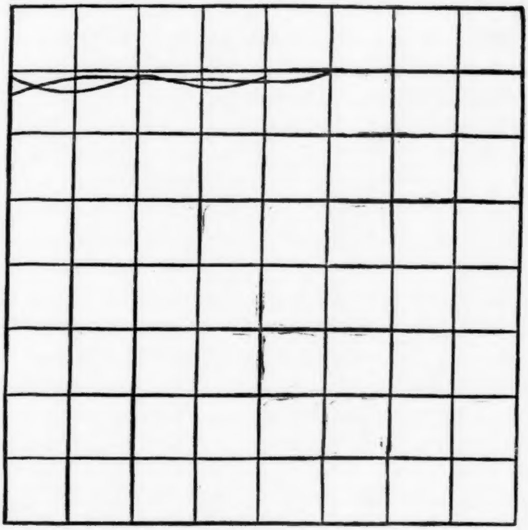

Fig. 7.

It is perhaps unnecessary to call attention to the fact that the capacity of a dielectric for rapid discharges is very different from its capacity for slow discharges. In the paper of Lorenz, already cited, the value of the dielectric capacity of glass was determined by slow methods, and used to test an equation in which the capacity of glass appears under very rapid charging and discharging.

Boltzman * and Klemencin † have experimented on the specific inductive capacity of gases and vapors, and it is seen from their results that the agreement between the square root of the capacities of the simple gases and μ, the index of refraction for light of these gases, is quite close, as is demanded by Maxwell's electromagnetic theory of light. A marked difference, however, was found to exist in the case of more complicated molecules, — sulphurous acid, or ethyl bromide, for instance. It is probable that the changes of specific capacity of heterogeneous media under rapidly alternating forces constitute an important factor in considering the possible agreement between Maxwell's theory of light and the results of experiment.

In order to see if an intense magnetic field could modify the trans-

* Pogg. Ann., Vol. CLI. p. 403, 1875.

† Abstract of Journal of the Society of Telegraphic Engineers, 1886, p. 108.

mission of electrical waves through a dielectric, the following experiment was tried. A glass Leyden jar, 2.5 cm. in diameter and 28 cm. in height, connected with our inductance circuit, was placed inside a coil consisting of 728 windings of large wire. The outer and inner radii of this coil were 27.7 cm. and 34 cm. Its height was 40.5 cm. The magnetic field in this coil was supplied by a Gramme machine, which gave a current through the coil of approximately thirty amperes. It was expected that a certain amount of the energy spent in producing the electrical waves would be consumed in a reaction on the magnetic field. The total duration of the electrical discharge did not appear to be notably affected by the magnetic field. Certain experiments seemed to show a decrease in the total number of electrical oscillations. A large number of experiments will be necessary to decide upon the effect of a magnetic field upon the passage of electrical waves through a dielectric. The difficulty of obtaining an electrical discharge under the same difference of potential made the experiment an extremely difficult one. The method seems to us to promise a discovery of Maxwell's displacement currents in dielectrics; and we are therefore continuing our researches in this direction with a modified form of apparatus.

Conclusions.

1. The electrical oscillations in the air between the plate of an air condenser show a periodicity extending through the entire range of oscillations. We believe that this periodicity is the analogue of the phenomenon of Hysteresis in Magnetism. A certain amount of the energy of the electrical discharge is spent in overcoming the dielectric viscosity of the air, and in straining the air dielectric. This strain is not immediately released in unison with the electrical surgings.

2. The discussion of our entire results shows unmistakably that electrical oscillations in air are not represented fully by the theoretical equations employed by Hertz. Since the latter writer has taken the term *resonance* from the subject of acoustics, and has given it a new significance in relation to electrical waves, we are tempted to draw also an analogy from the subject of sound. Laplace showed that the discrepancy between the value for the velocity of sound in air calculated from the theoretical equation, and that obtained by experiment, was due to a transformation of energy in heating and cooling the air during the passage of the sound wave. Our experiments on the transmission of electrical waves through the air show also that the values calculated from the theoretical equation do not agree with the

experimental values. The discrepancy, we believe, can be explained also by a consideration of the transformations of energy in the dielectric.

3. The periodicity which we have studied is most manifest when the variable capacity of the air condenser bears a suitable relation to the time of the electrical surgings.

4. The electrical waves are apparently unaffected by passing through glass which is placed in an intense magnetic field, the direction of the electrical strain being perpendicular to that of the magnetic strain. The displacement currents of Maxwell in this case do not appear to affect the time of electrical surgings. This conclusion, however, may be modified by experiments which we shall try on a more extended scale.

IX.

CONTRIBUTIONS TO AMERICAN BOTANY.

By Sereno Watson.

Presented June 12, 1889.

1. *Miscellaneous Notes upon North American Plants, chiefly of the United States, with Descriptions of New Species.*

Arabis humifusa (*Sisymbrium humifusum*, Vahl). The typical form of this Greenland species has been collected at Ungava Bay in northern Labrador by Mr. L. M. Turner, and a form with the lower leaves and base of the stem pubescent at York Factory on Hudson's Bay by Mr. James M. Macoun and Dr. Robert Bell. The mature pods of this variety are those of an *Arabis*, with the seeds narrow and wingless, and the radicle partially incumbent upon the cotyledons, as it is represented in the figure of the species given in Flora Danica (t. 2297). The characters accord with those of several other species which have usually been recognized as belonging to *Arabis*, though discrepant from the more typical species of the genus. Of these species (*A. lyrata*, *A. dentata*, *A. spathulata*, *A. humifusa*, and *A. Hookeri*, Lange) I would form a section *Pseudarabis*, as proposed by me in the recent new edition of Gray's Manual (p. 67), characterized by very small oblong or elliptical wingless seeds, having the cotyledons rarely strictly accumbent. They are all biennial or perennial, the pubescence of simple or rarely forked hairs.

Arabis Howellii. Perennial, with short stems (1 to 4 inches high) from a branching cespitose caudex, glabrous: leaves glaucous, entire, the lower linear-oblanceolate, an inch long, often sparsely ciliate toward the base, the few cauline narrowly oblong, obtusish, sessile, somewhat clasping but not cordate nor auriculate at base: flowers few, pale or bright pink, 3 or 4 lines long: pods erect, 1½ inches long by 2 lines broad, acuminate; stigma sessile; valves nearly nerveless: seeds orbicular, broadly winged. — Collected at Ashland Butte, Siskiyou Mountains, Oregon, by Mr. Thomas Howell in July,

1887; also by Mr. W. H. Shockley, August, 1888, in the White Mountains of Mono County, California, at 11,000 feet altitude.

STREPTANTHUS (EUCLISIA) LEMMONI. Annual, glabrous, paniculately branched: lower leaves unknown, the upper cauline lanceolate, auricled at base; rameal bracts ovate to orbicular, cordate-clasping with very short lobes: flowers rather small (2 to 4 lines long), the sepals acuminate with recurved or spreading tips; petals narrow, apparently white: filaments distinct: pods 2 or 3 inches long, narrow, on short pedicels; stigma sessile. — In the Santa Catarina Mountains, Arizona; collected by Mr. J. G. Lemmon, 1880.

STREPTANTHUS BARBATUS. Glabrous and glaucous; stems apparently several from a perennial (?) root, simple or at length branching: leaves crowded, uniform and nearly equal, cordate, sessile and clasping, obtuse or acutish, 9 lines long or less; floral bracts none: flowers purple, 3 or 4 lines long; sepals obtusish, setosely bearded near the apex: filaments distinct: pods spreading, on pedicels 1 to 3 lines long, curved, 1 or 2 inches long by 1½ lines broad; stigma sessile or nearly so: seeds narrowly margined. — Sandy bottoms along the upper Sacramento, first collected by the botanists of the Wilkes Expedition (*S. tortuosus*, Gray in Torr. Bot. Wilkes, 227), and rediscovered by Mr. Lemmon in 1879.

STREPTANTHUS ARIZONICUS. Annual or biennial (?), glabrous and glaucous, usually stout and tall, branching: leaves rather thin, entire or nearly so, acute, the lower oblong-lanceolate, petiolate, not ciliate, the upper oblong- to narrowly lanceolate, with rounded auricles: flowers pale; sepals strongly saccate; petals narrow, 6 or 7 lines long: filaments distinct: pods erect or ascending, 2 or 3 inches long by 2 or 2½ lines broad, obtuse or acute, with a broad sessile 2-lobed stigma: seeds very broadly winged. — In the mountains of southern Arizona, collected by C. G. Pringle in 1881, and later by S. G. Parish and J. G. Lemmon (n. 4170).

STREPTANTHUS * CAMPESTRIS. Annual or biennial, glabrous and

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* The known species of *Streptanthus* may be grouped as follows. —

§ 1. EUSTREPTANTHUS. Flowers large, the blade of the petals broad. Filaments distinct. Pods erect or ascending. Glabrous annuals.

* Floral bracts conspicuous.

1. S. BRACTEATUS, Gray. — Southwestern Texas.

* * Floral bracts none or minute.

2. S. MACULATUS, Nutt. — Arkansas and eastern Texas.
3. S. PLATYCARPUS, Gray. — Western Texas to Sonora.

glaucous, stout, 2 to 4 feet high, branching: leaves rather thick, acute, often irregularly toothed, the teeth at first setosely tipped and the leaf sparingly setose-ciliate near the base; cauline leaves lanceolate or oblanceolate: flowers more or less dark purple, 4 or 5 lines long, the sepals often hairy at the tip: filaments distinct: pods spreading and curved, 3 to 6 inches long by about a line broad, beaked with a short stout style and shortly lobed stigma: seeds winged. — At Campo, near the southern boundary of California; George R. Vasey and S. G. Parish in 1880. A specimen collected by the latter in the San Bernardino Mountains is apparently the same.

SILENE (CONOSILENE) MULTINERVIA. Annual, erect, sparingly branched, glandular-pubescent, about a foot high: leaves linear to linear-oblong, acute, the lowermost narrowly oblanceolate, 1 or 2 inches long: inflorescence dichotomously cymose; bracts linear: calyx narrowly ovate, 20–25-nerved, 5 or 6 lines long, the acuminate teeth usually purple-tipped; petals purplish, scarcely equalling the calyx, without appendages or auricles, emarginate: filaments glabrous, included: capsule nearly sessile, oblong-ovate, included: seeds minute,

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§ 2. EUCLISIA, Nutt. Petals narrow (the blade scarcely broader than the claw), undulate-crisped.

* Filaments distinct; cauline leaves clasping and auriculate; pods not reflexed.

+ Annuals; branches bearing round-cordate bracts, which also frequently subtend or alternate with the lower pedicels.

4. S. TORTUOSUS, Kell. — Northern California.
5. S. DIVERSIFOLIUS, Watson. — Northern California.
6. S. LEMMONI, Watson. — Arizona.

+ + Glabrous and glaucous mostly simple-stemmed biennials or perennials (?), with the broad thickish leaves obtuse or only acutish, the cauline cordately clasping; sepals obtuse, usually more or less setose.

7. S. BARBATUS, Watson. — Northern California.
8. S. CORDATUS, Nutt. — From the Sierra Nevada to Colorado.

+ + + Glabrous and glaucous annuals or biennials (?), with cauline leaves lanceolate and acute.

9. S. ARIZONICUS, Watson. — Southern Arizona.
10. S. CAMPESTRIS, Watson. — Southern California.
11. S. CARINATUS, Wright. — W. Texas to southern Arizona and Chihuahua.

* * Filaments distinct; pubescent annual, with sagittate leaves; pods narrow, reflexed.

12. S. HETEROPHYLLUS, Nutt. — Southern California.

* * * Filaments distinct; leaves not clasping nor auriculate; pods narrow.

+ Glabrous and glaucous biennial (?).

13. S. (?) HOWELLII, Watson. — Southern Oregon.

tuberculate, not crested. — Found near Jamuel, San Diego County, by C. R. Orcutt in April, 1885, and on the island of Santa Cruz, California, by T. S. Brandegee in 1888. The only representative in America of a small section of the genus (including *S. conoidea*, etc.), which is otherwise confined to the Mediterranean region and central Asia.

SILENE SHOCKLEYI. Slender, 3 to 8 inches high, puberulent throughout: leaves linear-oblanceolate, an inch or sometimes 2 inches long: flowers few or often solitary: calyx viscid-pubescent, cylindrical, 6 to 8 lines long, the acute lobes $1\frac{1}{2}$ lines long; petals rose-colored to greenish, the auricled claws more or less exserted, with broad and more or less laciniate appendages and the blade (3 lines long) equally cleft to below the middle: stamens and style equalling the petals. capsule oblong, long-stipitate: seeds tuberculate on the back. — On the White Mountains in Mono County, California, at 12,000 feet altitude; W. H. Shockley, August, 1888. Of the *S. Oregana* group.

BUDA BOREALIS, Watson in Gray's Manual, 6 ed., p. 90. A glabrous diffusely branched annual, with very narrow leaves an inch long or less: pedicels 2 to 6 lines long, ascending or often widely spreading: sepals and petals (white) scarcely a line long: stamens

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+ + Annuals.

14. S. LONGIROSTRIS. (*S. longifolius*, Benth., var., Torr. in Pacific R. R. Rep. 4. 65. *Arabis longirostris*, Watson, King's Rep. 5. 17, t. 2.) — East of the Sierra Nevada from Washington to Utah, Sonora, and Lower California.

15. S. (?) FLAVESCENS, Hook. — Central California.

* * * * One or both pairs of the longer filaments connate; cauline leaves more or less sagittately auriculate (scarcely so in n. 17); annuals, with narrow pods.

+ Sepals nearly equal; pods ascending or spreading.

++ Both pairs of filaments connate; seeds wingless.

16. S. BREWERI, Gray. — Central California.

++ ++ One pair of filaments connate; seeds winged.

= Glabrous.

17. S. HYACINTHOIDES, Hook. — Indian Territory to Texas.

18. S. BARBIGER, Greene. — Central California. Calyx sometimes glabrous.

19. S. NIGER, Greene. — Central California.

= = Pubescent.

20. S. HISPIDUS, Gray. — Central California.

21. S. GLANDULOSUS, Hook. (*S. peramœnus*, Greene. *S. albidus*, Greene, a white-flowered form.) — S. Oregon to San Luis Obispo County, Calif.

+ + Sepals very unequal, the outer much dilated; pods reflexed, narrow.

22. S. POLYGALOIDES, Gray. — Central California.

variable in number: capsule ovate to oblong-ovate, twice longer than the calyx or more: seeds variable as in *B. marina*, usually wingless and smooth or nearly so. — On the coast from Labrador to eastern Maine: Bonne Esperance, Labrador, and Rimouski County, Quebec (J. A. Allen); Anticosti and Prince Edward Islands (J. Macoun); Kent Co., N. B. (J. Fowler and J. Macoun); Eastport, Maine (W. G. Farlow). This plant is clearly distinct from *B. marina*, as has been pointed out by Dr. Britton (Torr. Bull. 16. 127), who refers it with little doubt to *Spergularia salina*, Presl. This, however, is generally regarded as merely a synonym for one of the forms of *B. marina.* I have been unable to identify our plant with any foreign species, and have given it a specific name having reference to its extreme northern habitat. In choosing between the two generic names proposed by Adanson, *Tissa* and *Buda*, which are on an equality as respects priority of publication, the adoption of *Buda* by Dumortier in 1827 in my opinion leaves no room for debate. In this decision I have reason to believe myself also in accord with the best botanical authorities of England. In my use hitherto of *Lepigonum*, "Fries," in preference to *Spergularia*, Presl, for the name of this genus, I have been in error through overlooking a note by Fries upon the final page of his *Flora Hallandica*, where, in correction or definition of his previous statement, he expressly makes *Lepigonum* a subdivision of *Arenaria*. The first one to use *Lepigonum* as a generic name was Wahlberg in his *Flora Gothoburgensis* (1820–24), which was subsequent to Presl's adoption of the name *Spergularia.*

TRIFOLIUM CATALINÆ. Annual, low, branching from the root, appressed villous-pubescent, the ultimate or penultimate nodes of the branches elongated and bearing a single or two approximate sessile heads subtended each by a nearly sessile trifoliate leaf: leaflets oblong-obovate, obtuse or broadly emarginate, erosely dentate, 3 or 4 lines long; stipules ovate or ovate-lanceolate, acuminate, entire: heads small, ovate; flowers sessile in whorls: calyx-tube coriaceous, narrow-campanulate, much shorter than the attenuate-subulate erect and rather rigid plumose teeth; corolla narrow, purplish, little exceeding the calyx. — Santa Catalina Island, California; T. S. Brandegee, May, 1890. A remarkable species, unlike ordinary American forms and of a distinct European type, most nearly resembling *T. saxatile* of the high Alps of Switzerland. In this respect it is a counterpart of the *Silene multinervia*, described on a previous page, and a few other species, and even genera, which form an interesting element in the flora

of the Californian coast. This species, like the *Silene*, has been compared with the European material at Kew through the kindness of Prof. Oliver and Mr. Baker. It differs from *T. saxatile* in the more unequal nodes of the stem, the more dentate and not bifidly emarginate leaflets, and the more coriaceous calyx with longer and more rigid teeth.

ASTRAGALUS (HOMALOBUS) FORWOODII. Annual, the several ascending stems about a foot high, sparsely covered with a fine pubescence: leaflets 5 or 6 pairs, linear to linear-oblong, 6 to 9 lines long: peduncles exceeding the leaves, bearing short loose racemes of small (4 or 5 lines long) deflexed flowers: calyx campanulate, the narrow teeth nearly equalling the tube; corolla whitish with a dark purple keel: pods deflexed, long-stipitate, thin-coriaceous, flattened, the ventral suture straight and the dorsal much curved, 9 to 12 lines long. — Black Hills of S. Dakotah, in dry rocky places in creek bottoms; Dr. W. H. Forwood, U. S. A., May, 1887. Near *A. stenophyllus*, Torr. & Gray (*A. filipes*, Torr.).

VICIA THURBERI. Annual, about a foot high, the young leaves, etc., pubescent, becoming glabrous: leaflets 4 to 12, narrowly linear, acute, 3 to 7 lines long; stipules small, subulate-lanceolate or linear, not at all sagittate, entire: peduncles short (3 to 6 lines long), bearing one or rarely two small white or purplish flowers: calyx nearly glabrous, the teeth rather short-acuminate: pods glabrous, sessile, oblong, obliquely acute at each end, about 9 lines long by 2½ or 3 broad, 5–7-ovuled. — From southern Utah and Colorado to Arizona and New Mexico; collected by Thurber (n. 150 and 299), Wright (n. 1350), Parry (n. 33, of 1874), Lemmon (n. 50, of 1880), Brandegee, etc., and referred to the Californian *V. exigua*, Nutt. That species is a taller plant, with similar foliage and fruit, but the stipules narrowly semi-sagittate and the more slender peduncles (1 to 2 inches long) usually 2–3-flowered, the flowers approximate. The only Nuttallian specimen of *V. exigua* in the Gray Herbarium was collected by Gambel on Catalina Island, and is the same as others collected by Coulter, Samuels, Thurber (San Diego), Bolander (Los Angeles), and M. E. Jones (Encenada, Lower California). The original description in Torrey & Gray's Flora seems to include also the next species.

VICIA HASSEI. Often tall: leaflets 3 to 6 pairs, linear to narrowly oblong, acute or obtuse and apiculate, or more frequently truncate and emarginate or toothed at the apex; stipules semi-sagittate with the rather broad lower lobe usually 2–4-toothed: peduncles 6 to 15 lines long, 1-flowered or sometimes remotely 2-flowered: pod more

attenuate at each end and short-stipitate, 5–9-ovuled, 9 to 16 lines long. — On open grassy hills about Los Angeles, California, growing with *V. exigua;* Dr. H. E. Hasse. Also collected at Santa Cruz by Dr. C. L. Anderson, at Benicia by Dr. Bigelow (*V. exigua*, var. (?) *Californica*, Torr. in Pac. Railroad Rep. 4. 76), and on Guadelupe Island by Dr. Palmer.

STROPHOSTYLES ANGULOSA, etc., Ell. The characters which distinguish those species of *Phaseolus* that were separated by Elliott under the name of *Strophostyles* are so marked that the restoration of the genus has long seemed to me desirable, for which the revision of the Manual has given an opportunity. These peculiarities are the sessile or very nearly sessile capitately clustered flowers, never racemose, the less curved and never spirally coiled keel and style, and the more or less mealy-pubescent quadrangular or subcylindric seed, subtruncate at the ends and with a narrow hilum half its length or more. Bentham's section *Strophostyles* is based mainly upon the production of the stipules below the insertion, which is not the case in our species. Elliott's specific names are to be retained for his species, and to these is to be added *Phaseolus pauciflorus*, Benth. The *P. pauciflorus*, Dalz., of the Indian flora, can therefore stand.

ERIOGYNIA (KELSEYA) UNIFLORA. Very densely cespitose (2 or 3 inches high), with numerous slender branching stems densely covered with persistent imbricated leaves, which are light green becoming brownish, narrowly oblong-oblanceolate, 1 to 1½ lines long, nerveless, acute, entire, silky-villous: flowers solitary, terminal (often apparently lateral from the prolongation of a branch), equalling the leaves, very shortly pedicellate: calyx-lobes oblong-ovate, obtuse, villous; petals a half longer, linear-spatulate, obtuse or emarginate: stamens 10, distinct, long-exserted, inserted outside of the thickened margin of the disk: carpels usually 4 (or 5, alternate with the sepals), distinct, oblong, somewhat hairy on the ventral edge, coriaceous in fruit and more or less dehiscent by both sutures; styles elongated, stigmatic at the narrow apex: seeds 3 or 4, linear-oblong, with a thin close testa. — Discovered at the "Gate of the Mountains," near Townsend, Montana, on precipitous cliffs bordering the Missouri River, by Rev. F. D. Kelsey, on 4th July, 1888.

The habit and inflorescence of this plant are remarkable among the *Spiræeæ*. With the exception, however, of its solitary flowers it closely resembles *Spiræa cæspitosa*, which has been hitherto retained in *Spiræa* as a section *Petrophytum*, as proposed by Nuttall, distinguished from the typical species by its racemose inflorescence and low

habit. The genus *Eriogynia* is separated from *Spiræa* by its cespitose habit, peculiar foliage, racemose inflorescence, and loose seed-coats. It is described also as having united filaments, but this does not appear to be the case. The staminodia attributed to it are merely the crenate lobings of the margin of the disk. It is therefore only in its foliage and seed-coats that it differs from *Petrophytum*. The dehiscence of the coriaceous carpels by both sutures is the same in both. No more satisfactory disposition of our present abnormal species occurs to me than to transfer the section *Petrophytum* (excluding the additional species referred to it by Maximowicz) to *Eriogynia*, and to add *E. uniflora* as a section *Kelseya*. This leaves *Spiræa* somewhat more homogeneous, and brings together species that are similar in their dwarf habit and not essentially unlike in other respects. The determinate inflorescence of *Kelseya* occurs also in *S. Ulmaria*, etc., and in *S.* (*Chamæbatiaria*) *Millefolium*.

The genus *Spiræa* has been recognized generally, and by botanists of the highest authority, as a composite one, which it was better to retain as made up of a number of well marked sections than to divide. The one notable exception is Maximowicz, who has made a very careful study of the whole group and whose conclusions are not to be rejected unadvisedly. In addition to *Physocarpus*, as distinct from *Neillia* * (to which it was referred by Bentham & Hooker), and *Eriogynia*, which genera seem to me well founded, he has separated several other genera, placing *Aruncus* and the Asiatic *Sibiræa* in his group *Spiræeæ*, — *Chamæbatiaria* (*S. Millefolium*), with the Old World *Sorbaria* † and *Spiræanthus*, among his *Gillenieæ* (as stipulate and having the carpels opposite the sepals instead of alternate with them), — *Holodiscus* (*S. discolor* and the very similar S. American *S. argentea*) among the *Potentilleæ*, — and *Filipendula* (*Ulmaria*) among the *Sanguisorbeæ*. The two latter genera are removed from

* The *Neillia capitata*, Greene, can be in no way separated from the ordinary *P. opulifolius*. His *N. malvacea* also, judging from the characters, appears to be a common form of *P. Torreyi*, though there are perhaps characters other than those given by him upon which that species can be divided.

† As respects the names adopted by Maximowicz, *Sorbaria* as the sectional name of Seringe he considers as having precedence by right of priority over Lindley's later generic name *Schizonotus*. Both names, however, are antedated by Rafinesque's *Basilima* (1815), and this makes it unnecessary in any case to disturb the *Schizonotus* of Dr. Gray. *Filipendula* is rightly preferred to *Ulmaria*, inasmuch as it was adopted by Linnæus himself in several of the early editions of the *Genera*, and the genus was definitely characterized by him as the equivalent of both the Tournefortian genera.

the former groups on account of their indehiscent 1-seeded fruit, which is called an achene. But the carpels do not become such achenes as characterize the tribes to which he refers these genera, where the ovules are solitary, for the ovules are here always two and pendulous, while the mature fruit here, though indeed tardily or perhaps never dehiscent, still is found to open more or less readily by the ventral suture on dissection. Focke (in Engler & Prantl) recognizes this objection, and accordingly forms two subtribes, *Holodisceæ* and *Ulmarieæ*, for the two genera, quite unnecessarily, for they fall very naturally among the *Spiræeæ* and *Gillenieæ*. In fact *Holodiscus* * is a true *Spiræa*, except in the thinner and less dehiscent carpels and fewer ovules, and may well be kept as simply a section of that genus. The Mexican *S. parvifolia* appears, from the descriptions that are given of it, to belong rather to this section than to the section *Petrophytum*, where it is placed by Maximowicz. *Filipendula* is much more distinct in its stipules and divided leaves, cymosely paniculate inflorescence and capitate stigmas, and is more nearly related to *Gillenia*. Too great stress should not here be laid upon the position of the carpels (in *Filipendula* alternate with the sepals when of the same number), as their number may be considered as normally ten in all cases, with irregular or regularly alternate suppression. Focke includes *Chamæbatiaria* in *Sorbaria*, but why he does not with as good reason include *Spiræanthus* is not evident. The three genera are closely allied, very much in the same way as the three sections of *Eriogynia*. But *Chamæbatiaria* is sufficiently well marked to be retained as the American representative of the group. Finally, the separation of *Aruncus* upon its herbaceous habit, compound leaves, diœcious racemose-paniculate inflorescence, etc., leaves *Spiræa* itself still a large genus, but well defined, and with a good degree of uniformity in its characters.

Eremiastrum Orcuttii. Pappus consisting of five white oblong-ovate laciniate paleæ and as many inner alternate bristles twice as long: in every other respect — habit, foliage, pubescence, involucre, etc. — the nearly exact counterpart of *E. bellioides.* — Collected in the southeastern part of the Colorado desert, in San Diego County, California, by C. R. Orcutt, April, 1889. By the character of the pappus this plant is a *Chætopappa*. From its close resemblance to

* The ovules in the species of this section seem to be very often abortive. Upon the many apparently mature specimens of the forms of *S. discolor* in the Gray Herbarium I have succeeded in finding but a single seed.

E. bellioides it might be supposed to be a variety of that species, but no intermediate forms are detected among previous collections.

Aster Forwoodii. Of the *A. puniceus* group, stout and leafy (2 feet high), rough-pubescent: leaves large (4 inches long), sessile, ovate to lanceolate, short-acuminate, narrowed to a broad subauriculate base, coarsely serrate, very scabrous, hairy on the veins beneath; bracts of the corymbose panicle small and narrow: heads large (6 lines high); scales rigid, very unequal, short-acuminate with lax or squarrose herbaceous tips: rays purple, 4 to 6 lines long. — Black Hills of S. Dakota; Dr. W. H. Forwood, U. S. A., August, 1887. A strongly marked species, clearly distinct from *A. puniceus* and *A. Cusickii*, and in habit much resembling *A. foliaceus*, var. *Canbyi*.

Artemisia Forwoodii. Biennial, erect, 2 feet high, the simple stem bearing numerous axillary erect narrow and slender panicles: leaves canescent both sides with a short villous pubescence or the upper glabrous above, twice pinnately parted into linear acute segments; bracts of the glabrous inflorescence small, linear, entire: heads numerous, small (1 to 1½ lines broad), globose-campanulate, with thin and subscarious greenish scales, 15–20-flowered. — Black Hills of S. Dakota; Dr. W. H. Forwood, September, 1887. Resembling *A. discolor*, with very numerous smaller subglobose heads in an elongated narrow compound panicle.

Lepidospartum latisquamum. A compact shrub 3 to 5 feet high, with numerous erect branches, floccose-tomentose and angled with mostly continuous lines of prominent greenish glands: leaves filiform, acute, an inch long or less: heads clustered at the ends of the branches, about 5-flowered; involucral scales broad and appressed, ovate to oblong, very obtuse, rigid and scariously margined, tomentose: corolla very deeply cleft: achenes densely villous, the long silky hairs passing into the very copious pappus. — Soda Spring Cañon, Esmeralda County, Nevada, at 6,000 feet altitude; W. H. Shockley, August, 1888. The anthers are almost caudate at base, but for which character the genus might be considered most nearly allied to *Bigelovia*.

Hieracium (Stenotheca) nigrocollinum. Subscapose, a foot high, sparsely hirsute throughout with white hairs: radical leaves thin, oblong-spatulate, obtuse, entire, the one or two on the base of the stem oblanceolate and acute: heads rather few in a loose oblong raceme, on slender peduncles ½ to 1 inch long, somewhat rufous-tomentose and hispid, ½ inch long: flowers numerous and apparently white: achenes (immature) somewhat tapering upward and shorter

than the whitish pappus. — Black Hills, S. Dakota; Dr. W. H. Forwood, June, 1887. Allied to *H. Fendleri.*

Eriogonum (Eriantha) Alleni, Watson in Gray's Manual, 6 ed., p. 734. Perennial, white-tomentose; stems naked below the dichotomous branches, 1½ to 2 feet high: radical leaves long-petiolate, ovate-lanceolate, cuneate to subcordate at base, the blade 4 inches long, greener above; upper leaves in whorls of 4 or 5 at the nodes, short-petiolate, ovate to oblong or oblong-ovate, acute, the lower 1½ to 3 inches long, much reduced above: involucres tomentose, those in the forks short-pedunculate; flowers glabrous, on tomentose pedicels, yellow, the segments elliptical, very obtuse, scarcely over a line long. — Collected on rocks, about a mile from the White Sulphur Springs, W. Virginia, by Dr. T. F. Allen in 1874. Closely allied to the more southern *E. tomentosum*, which differs in its more leafy stem, the lower leaves oblanceolate and long-attenuate at base, the upper sessile, and in the larger tomentose white flowers with broadly lanceolate segments.

Spiranthes præcox, Watson, l. c. 503. (*S. graminea*, Lindl. (?), Gray, Manual, 4 ed., p. xcviii. *S. graminea*, var. *Walteri*, Gray, l. c., 5 ed., p. 505.) A comparison of specimens of true *S. graminea* (collected by Dr. E. Palmer in Jalisco, Mexico) with the plant of the Atlantic and Gulf coasts that has been referred to it, shows too important differences to permit the latter to be considered merely a variety. The more leafy stems of our plant, its broader and more hyaline and usually more acuminate bracts, its larger flowers, its narrower and much less recurved lip, the more acutely beaked rostellum, and the narrower capsule, should suffice to characterize it as a distinct species.

Iris Caroliniana, Watson, l. c. 514. Rootstock rather stout: leaves elongated, 3 feet long by 12 to 15 lines broad, thin and lax, bright green, not glaucous or scarcely at all so: stem slender, 2 feet high; peduncles 2-flowered; bracts scarious, exceeding the pedicels: ovary 8 lines long, bearing a cylindric-campanulate tube 6 lines long; petals distinct at base, the outer 3 inches long, broadly spreading, with a yellowish green claw veined with brown, the elliptical blade lilac veined with purple and with a yellow spot reaching to the centre; inner petals oblong-spatulate, 2½ inches long, the blade lilac and claw yellowish: anthers as long as the filaments: wing of the stigma continuous with the erosely toothed lilac crest: capsule nearly 2 inches long, oblong, somewhat triangular with very rounded angles: seeds in one row in each cell, very large (4 or 5 lines broad and 2

lines thick), pale brown. — Cultivated in the Botanic Garden, Cambridge, from roots collected in 1888 near Wilmington, N. C., by Mr. W. A. Manda. Resembling in some respects *I. versicolor* of the Northern States, as it has been generally understood, which doubtless also includes the *I. Virginica* of Linnæus as represented by the original Gronovian specimen preserved in the herbarium of the British Museum. That species differs most notably in its erect glaucous and often much shorter leaves, and its very much smaller seeds in two rows in each cell. There are also less obvious differences in the coloring and shape of the smaller flowers. It varies to a considerable degree, especially in size, but in its main characters it appears to be constant and well defined.

SISYRINCHIUM ANGUSTIFOLIUM, Mill., and S. ANCEPS, Cav. Upon comparison of plants of these species growing side by side near Cambridge on the 1st of June, 1890, the differences in the inflorescence were found to be constant. The glaucous hue was much more decided in the latter, while the flowers were indistinguishable, except that in *S. anceps* they were somewhat darker and the yellow spot at the base of each petal broad and truncate or emarginate at the top, but in *S. angustifolium* somewhat narrowed and irregularly rounded above. This latter species was already nearly past bloom, with the older capsules and seeds of full size; the other was just coming into bloom.

CAMASSIA HOWELLII. Bulb rather small, bearing few leaves about a foot long by 2 to 5 lines broad: flowering stem and elongated many-flowered raceme nearly 2 feet high; pedicels spreading, becoming 9 to 12 lines long, at least twice longer than the linear bracts: petals pale purple, $\frac{1}{2}$ inch long, 3- (rarely 4- or 5-) nerved: capsule broadly triangular-ovate, very obtuse, 3 lines long; cells 2–3-seeded. — At Grant's Pass, Oregon; Thomas Howell, 1889. Flowering in May; flowers opening at about 2 P. M., remaining open till sunset. Distinguished from other western species especially by the small capsules on slender widely spreading pedicels.

SABAL MEXICANA, Mart. A palm which in the present imperfect knowledge of the species cannot be distinguished from *S. Mexicana* was collected by Berlandier (n. 877, "*Corypha edulis*") near Matamoras, and has more recently been found on the Texan side of the Rio Grande near Brownsville by Dr. Gorgas and by Prof. C. S. Sargent. This is the same also as 314 Ervendburg, collected on the savannas near Tantoyuca in the Department of Vera Cruz. It is said to be frequently 20 or 25 feet high, with a well defined trunk

10 or 12 inches in diameter. The petioles are very stout ($1\frac{1}{2}$ inches broad at the summit), with a ligule 6 inches long, and the blade (3 feet long or more) cleft a third of the way down between the plaits, which are an inch broad. The spadix is elongated and slender; the calyx and petals ($1\frac{1}{2}$ lines long) strongly nerved. The berries are often in pairs, 9 lines in diameter, sweet and edible; seeds 5 or 6 lines broad by $3\frac{1}{2}$ thick, very much larger than those of any of the Atlantic States species.

WASHINGTONIA SONORÆ, Watson, Proc. Amer. Acad. 24. 79. Dr. Palmer has recently sent from La Paz, Lower California, additional foliage of this species, together with flowering specimens. The flowers and inflorescence resemble very closely those of the San Bernardino species, having the calyx and petals somewhat thinner and more scarious, and the spadix very slender and sparingly branched. The petioles of the older leaves (3 feet long above the sheath and tapering from 2 inches to 9 lines in breadth) are very strongly convex on the lower side, thinning abruptly toward the margin, especially below the middle. The margin is thickly beset with very stout variously curved spines, which are mostly connected by a thick web of floccose hairs. In the young plant the petioles are very slender (2 lines broad), with scattered spines on the margin.

It has been difficult to identify satisfactorily the *W. filifera* and *W. robusta* of the gardens with the native palms of southern California. These two species as shown by Wendland (upon whose authority they rest) in the palm-houses at Herrenhausen, and as represented by specimens received from him and growing at the Botanic Garden at Cambridge, are so evidently different that they may well be distinct, — the latter species having darker green and more shining leaves upon shorter and stouter petioles, which give a more robust appearance to the plant. The source of the seeds from which the original "*Brahea filifera*" was raised by Linden at Ghent in about the year 1869 (as narrated by Wendland in Bot. Zeit. 37. 65) is not stated. I am informed, however, by Mr. W. G. Wright of San Bernardino, that for some years after that date the only source of seeds for the market was the trees in Cantilles Cañon (and perhaps also Palm Valley) in Lower California near the Mexican boundary, from which places the San Francisco seedsmen obtained their supply. In later years seeds were procured from localities east of San Bernardino, and from these originated the *W. robusta*. So far as I am able to judge from photographs and from the material in the Gray Herbarium, the palms of San Bernardino County are this species,

differing in just the respects noted above from the palm of Cantilles Cañon. It is very probable that the true *W. filifera* occurs also north of the boundary in the mountains bordering the Colorado River. In consequence of the demand for seeds of two species which collectors have not learned to distinguish, it is probable that seedsmen have not always been scrupulous in regard to the names under which the supply was distributed.

PELTANDRA UNDULATA, Raf. The *Arum Virginicum* of Linnæus, with which the common *Peltandra* of the Northern States has usually been considered identical, was a composite species, and both of its component parts are uncertain. The plant described in *Hort. Cliff.* was probably a cultivated one, said by Linnæus to have been of American origin, but it certainly could not have been from the United States, as the colors ascribed to it prove beyond doubt. His other reference under the species is to the plant described by Clayton in the *Flora Virginica* of Gronovius, and the identification here is rendered doubtful by Clayton's phrase, "radice tuberosa, Rapæ simili, fervida et acerrima." The root of *Peltandra* has no resemblance to that of a radish or turnip, nor is it hot or very acrid.

Rafinesque made his *P. undulata* the type of the genus, "having 3 to 5 seeds and probably the real *Arum Virginicum* of Clayton and Linnæus." Other species, as *P. Canadensis*, *P. latifolia*, *P. heterophylla*, etc., he described as having one or two or three seeds. The species, however, is exceedingly variable in many respects. Extreme forms received from Mr. A. Commons of Wilmington, Del., seemed to indicate that two species might perhaps be distinguished; but a study of the forms growing near Cambridge shows that no division can be safely made. The leaves vary from narrowly sagittate, with acute or acuminate or more or less obtuse lobes, to very broadly hastate, the broader forms either triangular or more or less elliptical in general outline. The spathe and spadix are more or less oblique at base, the former from 4 to 8 inches in length and the spadix from 2 to 6 inches, bearing from 20 to 80 pistillate flowers, the fertile portion being from 4 to 12 lines long. The ovaries contain 1 to 5 amphitropous ovules, and the short style bears a more or less oblique truncate stigma. The mass of fruit enclosed in the persistent base of the spathe is $1\frac{1}{4}$ to 3 inches long, the smaller with 1-seeded fruits about 4 lines in diameter, those of the larger often $\frac{1}{2}$ inch long or more and 1–3-seeded. The white staminodia among the ovaries are irregular in form and arrangement, distinct, and much shorter than the ovary, never united into a cup or nearly equalling it, as represented by Schott and usu-

ally described. I have seen no specimens in which the spadix was so very much shorter than the spathe as it is shown in Hook. Exot. Fl. t. 182, nor any in which its upper part was naked. The spathe is convolute either to the right or left. The rootstock is short and very thick, densely covered below with stout fleshy roots, and it is without acridity or nearly so.

PELTANDRA ALBA, Raf. This species was based upon the *Calla sagittifolia* of Michaux, the *Caladium glaucum* of Elliott, which has more recently been referred by Dr. Chapman (following Kunth's suggestion) to the *Xanthosoma sagittifolium* of the West Indies. It is clearly a *Peltandra*, though differing strikingly from *P. undulata* in the dilated and expanded white ovate blade of the spathe and in the reddish fruit. The more slender spadix is only half the length of the spathe, and its pistillate portion about as long as the sterile. The ovules appear to be always solitary. As in the last, the staminodia are distinct, but more nearly equalling the ovary. This is the *P. Virginica* of Schott, as described and figured by him, though in the figure the spathe is represented only partially expanded. It has been imperfectly understood by Dr. Engler, who in his *Araceæ* has confused it to some extent with the last, especially in the synonymy. It is confined to the southern coast, from Wilmington, N. C., to Florida, and is a pretty species, well worthy of cultivation. The generic characters as given by Bentham & Hooker and in Engler's revision require modification, as also in the Manual.

RUPPIA OCCIDENTALIS. Stems comparatively stout: sheaths elongated, 1 to 2 inches long or more: flowers as in *R. maritima:* fruit unknown. — In saline ponds near Kamloops, British Columbia; Prof. J. Macoun, June, 1889. The specimens are only in flower, but are remarkably unlike all forms of *R. maritima* in the length of the sheathing base of the leaf.

ELEOCHARIS EQUISETOIDES, Torr. This species is referred by Boeckeler to the E. Asian *E. plantaginea*, from which it differs in the transversely linear reticulation of the nutlet. It also resembles the tropical American *E. interstincta*, R. Br., but has the nodes of the culm less crowded, the rather larger and more turgid nutlets less abruptly narrowed to the base, and the bristles shorter, very delicate and scarcely barbed. In *E. interstincta* the bristles are very stout and rigid, strongly barbed, and nearly a half longer than the nutlet.

PASPALUM ELLIOTTII, Watson in Gray's Manual, 6 ed., p. 629. The *Digitaria paspalodes* of Michaux is identified with what is known as *Paspalum distichum*, Linn., and with this must evidently go as

synonyms the *P. Digitaria* of Poiret and the *P. Michauxianum* of Kunth. Elliott supposed his *Milium paspalodes* to be the same as Michaux's plant, from which it is however distinct, as plainly appears from both his description and his figure. Failing to find any other species with which to unite it, I have given it the above name. As shown by Dr. Vasey, it belongs to Bentham's section *Anastrophus*.

ANDROPOGON FURCATUS, Muhl. The name "*A. Provincialis*, Lam.," has recently been revived for this species, — a name which was also published by Retzius (Obs. 3. 43) in the same year (1783) and for probably the same grass. Lamarck's species was based upon what was said to be a grass of Provence in southern France, which had been described and figured by Gerard in 1761, but which Lamarck had not seen in flower. The synonyms that are cited by Gerard and Lamarck are known to belong at least in part to *A. Ischæmum*, Linn., a common species of southern Europe. But Gerard's figure and description do not apply well to any Provençal grass that has since been discovered, nor to any grass so nearly as to our *A. furcatus*. It appears certain that *A. furcatus* was in cultivation in several of the gardens of Europe at or before Lamarck's time, as specimens are found in the Herbarium at Paris, ticketed as reported from Provence, and in the Linnæan Herbarium, where in fact, according to Sibthorpe and Kunth, it stands for the type of *A. Ischæmum*. The plant cultivated at Paris in 1835 as *A. Provincialis* is minutely described by Kunth, and the flower figured, and this is beyond doubt *A. furcatus*. It is highly probable, therefore, that the original *A. Provincialis*, aside from its synonymy, and *A. furcatus*, are the same species. But were this absolutely certain, Muhlenberg's name should still be retained. *Andropogon Provincialis*, like *Asclepias Syriaca*, is a false name, and it cannot be justifiable to make a change for the sake of reviving and perpetuating an error.

ERAGROSTIS CAMPESTRIS, Trin. Trinius cites as a synonym of this species *Poa nitida*, Ell., notwithstanding that Elliott describes his grass as having the spikelets on long pedicels and the axils glabrous, while the species of Trinius has the spikelets subsessile or very shortly pedicelled and the axils somewhat hairy. His description corresponds far more accurately with that of Elliott's "*Poa refracta*, Muhl.," which is considered by Dr. Chapman as a variety of *E. pectinacea*. It is distinct from that species in its more sparsely and divaricately branched panicle, the spikelets nearly or quite sessile along the branchlets, and the flowering glumes very acute or acuminate. It is also more glabrous, having only the throat of the sheaths

villous and the lower axils more or less bearded, the tuft reduced sometimes to only one or two hairs, as described by Trinius, the upper axils usually glabrous. The *Poa nitida* of Elliott appears to be a distinct species, having the branches of the panicle ascending, with the few spikelets terminal on long pedicels, and the glumes very acute, but less pointed than in *E. campestris.* It is wholly smooth and glabrous excepting the beard at the throat of the sheaths and a moderate roughness on the panicle and sometimes on the leaves. As the name *Eragrostis nitida* has been applied by Link to a different grass, this may be called E. ELLIOTTII.

GLYCERIA GRANDIS, Watson, l. c. 667. This grass has ordinarily been referred to *G. aquatica*, Smith (*Poa aquatica*, Linn.), of which it was made a variety by Torrey in his early publications. Recently it has been named *G. arundinacea,* Kunth, which is the same as *G. remota,* Fries. Our species differs from the last in its much stouter habit, larger, more erect and more branched panicle, the empty glumes broader, and the flowering glumes shorter, broader in proportion, and more obtuse. From *G. aquatica* it differs in its much narrower and smaller spikelets (2 or 3 lines long and 3–6-flowered), the more acute lower glumes, and the flowering ones more abruptly obtuse or truncate.

PUCCINELLIA, Parl. (*Atropis,* Griseb.) Following Hackel, Thurber, and others, this genus is kept distinct from *Glyceria* in the revised Manual, especially as it is needed for a number of western species which are not satisfactorily referable to either *Glyceria* or *Poa.* Its separation leaves both these genera much more clearly defined. The name *Atropis,* which originated with Trinius, is credited by Grisebach for the genus to Ruprecht, Fl. Samoied. (1845). But reference to the place cited shows that while Ruprecht was strongly disposed to consider *Dupontia, Arctophila, Atropis, Catabrosa* and *Phippsia* as equally good genera, and even used *Dupontia* and *Arctophila* as generic names upon the plates of some new species, yet throughout his text and descriptions they are all alike treated as subdivisions of the genus *Poa.* The perplexity under which he labored is shown by the expression with which he closes his discussion of the possible genera, — "Nubes et inania captant, qui generibus solum student, nec speciebus simul cunctis." The genus was first definitely published by Parlatore in 1848 under the name of *Puccinellia,* and then by Grisebach in 1853 as *Atropis.*

2. *Descriptions of New Species of Plants, from Northern Mexico, collected chiefly by Mr. C. G. Pringle, in* 1888 *and* 1889.

Thalictrum Pringlei. About two feet high, glabrous throughout, diœcious or subpolygamous: leaves once or twice ternate, petiolate; leaflets suborbicular, peltate, mostly large ($\frac{1}{2}$ to 2 inches in diameter), coarsely 5–9-toothed, not at all glandular: flowers in an open panicle, on slender pedicels, mostly nodding: anthers linear, long-apiculate: fruit compressed, nearly semicircular, strongly 3-nerved on the sides, 2 to $2\frac{1}{2}$ lines long, the elongated filiform stigma subpersistent: seed oblong, compressed, somewhat curved, shorter than the cell. — Slopes of the barranca near Guadalajara, Jalisco; June, 1889 (n. 2478).

Delphinium Madrense. Stem slender, from a thickened root, simple or branched, 2 feet high or less, pubescent with reflexed hairs below, glandular-hispid above: leaves 3-parted, the lobes subpinnately 5–7-cleft into linear-oblong segments, the lowermost less cleft, the upper reduced: flowers few, pale blue, in a slender raceme, rather small, with a narrow straight spur; lateral petals long-villous: carpels short, glandular-hispid. — In the Sierra Madre, near Monterey; May, 1889 (n. 3014). Resembling *D. pauciflorum*, and characterized by its slender habit, glandular-hispid pubescence, straight slender spurs, and long-villous petals.

Bocconia latisepala. Herbaceous annual, the stems many in a clump, 5 or 6 feet high; young branches and panicle glabrous: leaves broadly oblong, glaucous and nearly glabrous above, whitish-tomentose beneath, pinnately lobed to the middle, the sinuses rounded at base, the broad lobes obtuse or barely acutish, rather obscurely repand-dentate: sepals very broadly elliptical or nearly orbicular, 3 or 4 lines long, mostly longer than the rather stout pedicels: stamens 15: fruit nearly as in *B. frutescens*, 4 lines long, acutish at both ends, about as long as the stout stipe; style much shorter than the stigmas. — Collected in flower by Dr. E. Palmer at Guajuco, Nuevo Leon (n. 23 of 1880, *B. frutescens*, Watson in Proc. Amer. Acad. 17. 319, not of Linn.), and in fruit by C. G. Pringle (n. 1907 of 1888) on rich shaded slopes about the base and foothills of the Sierra Madre, south of Monterey.

Bocconia arborea. A tree 15 to 25 feet high and sometimes 2 feet in diameter, with deeply cracked corky bark; young branches and base of the slender panicle tomentose: leaves glabrous above, rusty-tomentose beneath, especially on the midvein and nerves, ovate

to oblong-lanceolate, deeply pinnatifid, the narrow lobes very narrowly acuminate, the smaller leaves only toothed or nearly entire: sepals broadly oblong, acute, 4 lines long: stamens 10 or 15, the filaments mostly very short (½ to 1 line long): style as long as or longer than the stigmas; fruit (immature) erect, 2 to 2½ lines long, equalling the stipe. — In rich mountain cañons near Lake Chapala, Jalisco; December, 1889 (n. 2445).

CAPSELLA (HYMENOLOBUS) STELLATA. Low and spreading, somewhat woody below, rather rigidly much-branched, canescent throughout with stellate pubescence: leaves narrowly oblanceolate, entire or obscurely few-toothed, 6 lines long or less: racemes sessile; flowers white: pods elliptical, somewhat obcompressed with deeply concave valves, stellate-pubescent, about 1½ lines long and equalling the divaricately spreading pedicels; cells 3–4-seeded. — On limestone ledges in Carneros Pass, Coahuila; September, 1889 (n. 2844, 2848). Habit nearly that of *C. Mexicana;* style variable in length.

ALSODEIA PARVIFOLIA. A much branched leafy shrub: leaves short-oblanceolate or narrow-rhombic, obtuse or acutish, cuneate at base, serrulate, glabrous or slightly pubescent on the nerves beneath, 3 to 15 lines long, usually much exceeding the nodes: flowers solitary in the axils, on pedicels 1 or 2 lines long, small (about a line long): fruit 2 lines long, the placentas 1-seeded. — In the mountains east of San Luis Potosi; 1890 (n. 3063). Remarkable for the numerous short nodes of the branches and for its small leaves.

POLYGALA PRINGLEI. Tall and slender (1½ or 2 feet high), closely resembling *P. paniculata*, but glabrous throughout, the raceme dense and narrowly cylindrical, and the smaller seed with a very minute hilum, nearly ecarunculate. — In wet places, plains of Guadalajara; October and November, 1889 (n. 2148, 2452). Distributed under the latter number as *P. paniculata.*

DRYMARIA LONGEPEDUNCULATA. Annual, very slender, the elongated branching stems recumbent, clothed throughout with a soft villous pubescence: leaves thin, broadly ovate, apiculate or shortly acuminate, truncate to rounded or cuneate at base, 3 to 5 lines long: peduncles axillary, elongated (1 to 3 inches), 1–3-flowered: flowers large; sepals thin, oblong-lanceolate, 2 lines long; petals twice longer, deeply parted and cleft: capsule stipitate. — Under ledges of the barranca near Guadalajara; November, 1888 (n. 2121). Of the *D. gracilis* group.

DRYMARIA TENUIS. Glabrous throughout, the stems very slender, from a slender branching rootstock, a foot long or less: leaves thin,

lanceolate to ovate-lanceolate, acute, cuneate at base, 2 to 5 lines long; stipules setaceous: peduncles terminal, capillary, 1–3-flowered: sepals very thin, lanceolate, acuminate, a line long; petals much shorter, bifid: capsule globose, sessile. — With the last (n. 2120).

DRYMARIA ANOMALA. Annual, glabrous or subpuberulent, the slender stems diffusely much branched, a foot high: leaves thickish, nearly sessile, ovate to lanceolate, acute, cuneate at base, 2 or 3 lines long; stipules setaceous: flowers in broad diffuse cymes, sessile at the nodes: sepals herbaceous and somewhat rigid, a line long, the two outer larger and ovate, the inner lanceolate; petals small, bifid: stamens 3: capsule globose. — Carneros Pass, Coahuila; September, 1889 (n. 2847).

HYPERICUM PAUCIFOLIUM. Annual, glabrous, sparingly branched, a foot high or more, with a few distant pairs of narrowly linear leaves 3 to 9 lines long: flowers racemose along the branches and solitary in the forks, on short pedicels: sepals narrowly lanceolate, the orange petals twice longer: stamens about 40: capsule 1-celled, equalling the sepals ($1\frac{1}{2}$ to 2 lines long); styles elongated, distinct. — In the Sierra Madre near Monterey; June, 1888 (n. 2266). Related to *H. fastigiatum*.

HYPERICUM PRINGLEI. Perennial, erect, glabrous and glaucous, nearly 2 feet high, with numerous short slender lateral branches: leaves spreading, narrowly oblong to oblong-spatulate or oblanceolate, obtuse, lighter beneath, $\frac{1}{2}$ to $1\frac{1}{2}$ inches long: flowers in mostly small and close terminal cymes: sepals narrowly lanceolate, acuminate, 2 lines long; petals twice as long, remaining twisted over the capsule: stamens numerous: styles 3, distinct; capsule 3-celled, ovate, equalling the sepals. — In the Sierra Madre near Monterey; June, 1889 (n. 3012).

MALVASTRUM SCHAFFNERI. A stout erect simple or somewhat branching perennial, 2 or 3 feet high or more, more or less densely stellate-pubescent throughout: leaves broadly ovate to ovate-lanceolate, subcordate at base, acute or acuminate, unequally serrate, 3 inches long or less, mostly hastately lobed, the short broad lobes rounded or acutish: flowers densely clustered in more or less compound axillary and terminal pubescent panicles, small: calyx 2 lines long or less, the acute deltoid lobes about equalling the white or whitish petals: carpels (10) small, nearly circular, smooth. — In the San Miguelito Mountains, near San Luis Potosi (n. 160 Schaffner, 1876); between San Luis Potosi and Tampico (n. 1036 Palmer, 1879, distributed as *M. vitifolium*); and at Carneros Pass, Coahuila

(n. 2849 Pringle, 1889). Remarkable for its numerous crowded small white flowers.

Oxalis Madrensis. Stems low and decumbent, from slender running rootstocks, branching, pubescent throughout: leaflets obovate, obtuse or usually slightly emarginate, equally short-petiolulate, ½ inch long or less: peduncles axillary, slender, about equalling or exceeding the leaves, bibracteate, 1-flowered: sepals thin and subpetaloid, purplish, ciliate, oblong-lanceolate, obtuse, 3 or 4 lines long; petals yellow, 5 lines long: stamens all equalling the styles: capsule not exceeding the sepals: seeds few, finely 10-costate, the ribs acutely tuberculate. — In the mountains near Monterey, July, 1889 (n. 2867). Allied to *O. Berlandieri*.

SARGENTIA; new genus of *Rutaceæ* (*Xanthoxyleæ*). Flowers perfect, or ovary sometimes abortive. Calyx small, 5-parted. Petals 5, imbricate, orbicular, spreading. Stamens 5, at the base of a thick lobed hypogynous disk. Ovary very deeply 5-lobed, sessile upon the disk. Style central, simple; stigma small, entire. Fruit an oblong-obovoid drupe (or double, the two parts coherent by the inner face), with fleshy epicarp and thin crustaceous endocarp. Seed solitary, attached by a long hilum to the inner angle, exalbuminous. Cotyledons flat and thick; radicle superior, very short. — A small tree, with alternate palmately 3-foliolate evergreen leaves, and small flowers in narrow axillary and terminal panicles.

S. Greggii. Leaflets shortly petiolulate, oblong-obovate, obtuse or acutish, 1 to 3 inches long, glabrate, the petioles and nerves minutely puberulent: panicles shorter than the leaves, tomentulose: sepals orbicular; petals a line long, exceeding the stamens: fruit yellow, 9 lines long. — First collected by Dr. Gregg near Monterey in flower, in February, 1847, ticketed as "Chapote amarillo" and described as bearing a small edible fruit. It occurs abundantly in the cañons about the base of the mountains surrounding Monterey as a large shrub or small tree with smooth gray bark, which cleaves off much as in *Platanus*. It was collected by Mr. Pringle in fruit in June, 1888, and in 1889 in flower (n. 2416). The generic name is given in recognition of the botanical services of Prof. C. S. Sargent, Director of the Arnold Arboretum, through whose assistance Mr. Pringle has been enabled to successfully prosecute his explorations in northern Mexico.

Amyris Madrensis. Very finely and somewhat densely pubescent, with slender branches leaves pinnate, 2 or 3 inches long; leaflets 2 to 4 pairs, thick, dark green, very shortly petiolulate,

obliquely rhombic, obtuse or retuse, cuneate at base, obscurely crenulate or entire, 6 to 10 lines long, very finely pubescent beneath, nearly glabrous above: panicles small and slender, axillary, shorter than the leaves: young fruit somewhat pubescent, oblong-obovate, 2 or 3 lines long. — On limestone ledges in the mountains near Monterey; May and July, 1889 (n. 2093).

DECATROPIS COULTERI, Hook. f. Specimens of this species in immature fruit, collected by Mr. Pringle in 1889 (n. 2558), have the carpels sessile and distinct, coriaceous, semicircular or reniform in outline, doubly wing-carinate on the back, and about 2 lines long. The solitary reniform seed is apparently exalbuminous, and is attached to the middle of the inner angle of the cell. The plant is a slender shrub, 6 to 20 feet high, branching sparingly near the summit, and with evergreen foliage. It grows in open clumps on the limestone ledges of the mountains about Monterey, apparently spreading and propagating by its roots.

BURSERA PRINGLEI. Glabrous throughout: petiole and very narrowly winged rhachis of the leaf slender and elongated (3 to 6 inches long); leaflets 5 to 12 pairs, rather thin and not rugose, linear-lanceolate and acuminate, serrate, 1 to 1½ inches long: racemes slender, 1 to 1½ inches long, 2–4-flowered, the curved pedicels 3 or 4 lines long: flowers unknown: fruit oblong-obovate, 3 lines long. — On rocky bluffs of the Rio Grande de Santiago near Guadalajara; October, 1889 (n. 2336). Near *B. Galeottiana.*

BURSERA PALMERI, Watson, var. GLABRESCENS. Leaflets 5 to 10 pairs, glabrous above or nearly so, very rugose, 6 to 10 lines long. — In the same locality (n. 2335).

BURSERA PUBESCENS, Watson, Proc. Amer. Acad. 24. 44, based upon foliage only, is proven by specimens collected during the past season by Brandegee and Palmer to be *Veatchia Cedrosensis*, Gray.

THOUINIA ACUMINATA. A tree (25 feet high) with slender branches, very minutely puberulent or glabrate: leaves 3-foliolate, the thin leaflets lanceolate, acuminate, narrowed at base, acutely serrulate, ciliolate, 2 to 4 inches long by 9 to 18 lines wide, about equalling the slender petioles: panicles slender, about equalling the leaves: flowers whitish, pedicellate, the stamens twice longer than the orbicular or round-obovate sepals and petals: fruit glabrous, the broadly divaricate wings 6 lines long. — In a barranca near Guadalajara; October, 1889, in flower; December, in fruit (n. 2485).

THOUINIA PRINGLEI. Branchlets and petioles stout, tomentose: leaves trifoliolate; leaflets finely pubescent above, tomentose beneath,

rather coarsely crenate-serrate, acutish or obtuse, 1 to 3 inches long, the terminal rhombic-obovate and petiolulate, the lateral obovate or elliptical and sessile: panicle stout, tomentose, equalling the leaves: flowers nearly sessile: sepals and fruit pubescent; wings ascending, 6 lines long. — Same locality; December, 1889, in fruit (n. 2567).

STAPHYLEA PRINGLEI. Resembling *S. trifolia;* lateral leaflets somewhat more rounded and unequal at base: capsule very broadly elliptical or nearly orbicular in outline, acute, 1½ to 2 inches long: seeds much larger (3 lines in diameter), dull, with a broad deep scar at base. — In cañons of the Sierra Madre, near Monterey; July, 1888, in fruit (n. 1936).

LUPINUS ERMINEUS. Perennial, stout and leafy, white throughout with very dense short-villous pubescence, appressed on the leaves and pods, elsewhere mostly spreading: leaflets usually 7, oblanceolate, acute, 15 lines long or less, somewhat shorter than the petioles: racemes nearly sessile, many-flowered, becoming much elongated; bracts linear, equalling the calyx, deciduous; pedicels very short (2 or 3 lines long in fruit): calyx scarcely gibbous at base, very villous, 3 lines long, the broad purple corolla 4 or 5 lines long: pod 6-seeded, an inch long by 3 lines broad. — Gravelly banks of streams near Zacatecas; October, 1888 (n. 1762). Near *L. Palmeri* and *L. niveus,* distinguished especially by the more villous character of the dense white pubescence.

DALEA CAPITATA. Woody, diffusely much branched, a foot high, glabrous or slightly puberulent: leaves small, the 5 to 9 leaflets ½ to 1½ lines long, obovate, emarginate: spikes capitate, dense, on very short terminal peduncles; bracts broadly ovate, acute or short-acuminate, subpersistent, equalling the campanulate scarcely nerved pubescent calyx: calyx-teeth acute; petals yellowish, 3 lines long: pod pubescent, included. — At Carneros Pass, Coahuila; September, 1889 (n. 2378). With the habit of *D. frutescens.*

BRONGNIARTIA NUDIFLORA. Shrubby, with the branchlets densely villous-pubescent and usually flexuous: leaves 4 or 5 inches long, of 4 to 6 pairs of oblong acute subcoriaceous and strongly reticulated leaflets, sparingly pubescent beneath and ciliate, 1 or 2 inches long; stipules deciduous: flowers apparently loosely racemose, in fascicles of 1 to 6, each fascicle subtended by a pair of thin villous semicordate stipule-like bracts; calyx and pedicels (each about ½ inch long) green and glabrous; corolla dark purple, 10 lines long: young pods glabrous, flat, attenuate below, 6–8-ovuled. — On rocky hills near Guadalajara; November and December, 1889 (n. 2128, 2980).

Desmodium (Chalarium) Guadalajaranum. Stem tall and stout, uncinate-hispidulous, as also the veins beneath the leaves and the inflorescence: upper leaves unifoliolate (lower unknown), subcoriaceous, very shortly petiolate, ovate-lanceolate, acute, rounded at base, strigulose, reticulate beneath, 2½ inches long; stipules semiovate, acuminate; stipels linear: flowers small, in diffuse terminal and axillary panicled racemes, the slender pedicels 3 to 5 lines long; bracts caducous: legumes glabrous, 1–4-jointed, equally indented both sides, the suborbicular dark-colored joints 1 or 2 lines long. — In cañons near Guadalajara; November, 1889 (n. 2829).

Cologania Pringlei. A low twiner, reflexed-hispid: leaflets oblong, or the odd one oblong-ovate, obtuse and apiculate or retuse, rounded or subcordate at base, villous with scattered appressed hairs, 1 to 2½ inches long: pedicels 2 to 4 in the axils or umbellate on a short peduncle (or near the base sometimes scattered upon an elongated peduncle), about equalling the calyx (4 lines long): corolla purple, 8 lines long: pod linear, straight, densely pubescent, 1½ or 2 inches long by 2½ lines wide. — Jalisco (n. 2788).

Bauhinea (Casparea) Pringlei. A shrub, 15 to 20 feet high: leaves suborbicular (3 inches long or more), on petioles an inch long or more, cordate at base, 9-nerved, cleft to below the middle, the sinus nearly closed by the contiguous obtuse lobes, nearly glabrous above, sparingly ferruginous-pubescent beneath: racemes axillary, rather many-flowered, becoming elongated: calyx puberulent, 8 lines long, exceeding the pedicel; petals 15 lines long, whitish with a purple stripe down the middle, narrowly oblong-lanceolate, the claws pubescent: sterile filaments bearded, the fertile stamen much shorter than the petals: pistil equalling the petals; fruit unknown. — On cool cliffs of the barranca near Guadalajara; 1888 (n. 1722).

Acacia glandulifera. A rigidly branched shrub with dark-colored bark: stipular spines divaricate, slightly curved, terete, 3 lines long: leaves very short, of one or rarely two pairs of pinnæ, somewhat puberulent; leaflets 5 to 7 pairs, thickish, linear-oblong, 1 to 1½ lines long: flowers capitate on axillary peduncles 3 or 4 lines long: pods coriaceous, dehiscent, linear, more or less torulose, covered with short rigid gland-tipped processes, 1¼ to 2½ inches long and 3 lines broad, 3–6-seeded. — At Carneros Pass, Coahuila; September, 1889 (n. 2861). Nearest to *A. constricta*.

Acacia Tequilana, Watson, Proc. Am. Acad. 22. 409. Pod thin and flat, straight, 1½ or 2 inches long by 3 lines broad, atten-

uate to a stipe ½ inch long, 3–7-seeded. — Collected in fruit by Mr. Pringle on hillsides near Guadalajara; October, 1889 (n. 2998).

SEDUM DIFFUSUM. Stems short, from a widely spreading branched fleshy underground rootstock, sparingly branched, glabrous, very leafy: leaves alternate, sessile or clasping, narrowly oblong, obtuse, 2 to 4 lines long: flowers in simple terminal loose elongated spikes; bracts mostly shorter than the flowers: sepals short, ovate, obtuse; petals white, twice longer, narrowly oblong, acute: stamens 10, very short: carpels becoming widely divergent above the broad base. — On dry limestone ledges in the Sierra de la Silla near Monterey; May and June, 1889 (n. 2273, 2509).

SEDUM JALISCANUM. Annual, slender, loosely branching from near the base, glabrous, 2 to 4 inches high, the lower branches elongated and subdecumbent: leaves scattered, rather thin, ovate and narrowed to a long petiole (in all 9 to 12 lines long), becoming more or less narrowly oblanceolate and gradually reduced and narrowed above: flowers solitary in all the axils, very shortly pedicellate: sepals narrowly linear, nearly equalling the linear-lanceolate acuminate white petals (1½ lines long), exceeding the carpels: stamens 10, the very slender filaments about equalling the petals: carpels erect or slightly spreading. — On shaded mossy rocks near Guadalajara; September and October, 1889 (n. 2192, 2451). Very peculiar among American species in its habit.

SEDUM ALAMOSANUM. Perennial, the rootstock densely branched and sending up numerous crowded stems at first clavate with the densely imbricated foliage, at length more elongated (3 or 4 inches long) and the leaves more scattered: leaves puberulent, terete, linear-oblong, 1½ to 2 lines long: inflorescence unknown. — Under shelving rocks in the Alamos Mountains, Sonora; Dr. Edward Palmer, 1890. A very peculiar species, much like *S. Greggii* in habit, but differing in its foliage.

COTYLEDON PRINGLEI. Stems stout, decumbent, a foot long or more, very leafy and branching: leaves (and branches) puberulent, rather thin, broadly oblanceolate, acute, mostly 1 or 2 inches long: racemes simple, terminal, the foliaceous bracts nearly equalling the flowers; pedicels 2 to 4 lines long: sepals narrowly lanceolate, acuminate, as long as the corolla (6 to 8 lines); petals united only near the base, red, very acutely and prominently carinate, acuminate: stamens a third shorter. — On dry shaded ledges of the barranca near Guadalajara; 1889 (n. 1853).

MYRIOPHYLLUM MEXICANUM. Stems stout: floral leaves narrow, pectinately pinnatifid or toothed, in whorls of 4 to 6, or in alternate

half-whorls, or scattered: flowers perfect; petals pink, orbicular, deciduous: stamens 4, with small elliptical anthers: fruit a line long, smooth, the narrow carpels rounded or acutish on the back. — In ponds in cañons of the Sierra Madre, Chihuahua; October, 1889 (n. 2017). Nearest to *M. ambiguum*, from which it differs in its stouter habit, broader petals (and flower-buds), shorter anthers, and larger fruit.

CUPHEA (DIPLOPTYCHIA) PRINGLEI. Tall (2 or 3 feet), very scabrous, slender: leaves opposite, narrowly lanceolate, acuminate, cuneate at base, 2 or 3 inches long, those on the branchlets much smaller and the upper cauline narrowly linear: flowers in a terminal glandular-hispid panicle, on slender alternate or opposite pedicels; calyx scarlet, narrow, 9 or 10 lines long, strongly gibbous at base, the teeth nearly equal; dorsal petals bright scarlet, oblong-obovate with a short claw, 5 lines long, the ventral minute: stamens 11, 4 shortly exserted: disk thick and pyramidal, suspended from the base of the ovary: seeds about 30. — In mountain cañons near Lake Chapala; December, 1889 (n. 2424). A very showy species, near *C. cordata* of Peru and Colombia.

BEGONIA UNIFLORA. Stem thick and fleshy from a small tuberous root, procumbent, a foot long or less, smooth and glabrous or somewhat verrucose: leaves thin and nearly glabrous, round-cordate, palmately 7-nerved, the margin dentately 7–11-lobed and sparsely toothed or denticulate, the teeth and sinuses often setulose, 2½ inches broad or less; stipules ovate-lanceolate, laciniately toothed; petioles (except the radical ones) shorter than the blade, bristly at the summit: peduncles axillary, 1-flowered; bracts ovate: flowers glabrous, rose-color, the staminate 2-petalous, the pistillate 5-lobed: stamens monadelphous, the orbicular anthers shorter than the filaments: ovary nearly equally 3-winged. — In the Sierra Madre near Monterey; August, 1889 (n. 2885). Probably of the section *Kniesbeckia*, but the ovary of the single pistillate flower was not in good condition for examination.

PASSIFLORA SUBEROSA, Linn., var. LONGIPES. Glabrous and very slender: leaves very thin, on very slender petioles 6 to 18 lines long, deeply 3-lobed, the narrow and nearly equal lobes acute or acuminate. — In the barranca near Guadalajara; September, 1889 (n. 2966).

APODANTHERA PRINGLEI. Stems slender, usually prostrate and rooting, scabrous: leaves thin, scabrous both sides, triangular-ovate, 1 to 3 inches long and nearly as broad, cordate at base with a deep

closed sinus, mostly hastate with broad rounded or truncate and usually sinuate lobes, the middle lobe acute: staminate flowers minute and very few, clustered on very short peduncles, green, hispid, tubular-campanulate, shortly toothed: anthers oblong, nearly straight: pistillate flowers in separate axils; corolla open-campanulate with spreading 5-cleft margin, about 3 lines long; ovary narrowly oblong, 4 lines long, exceeding the peduncle, obtusely quadrangular, slightly hispid on two opposite sides; placentæ 4 (as in *A. Palmeri*), many-seeded. — Under ledges near Guadalajara; November, 1888 (n. 2140).

MAMILLARIA (ANHALONIUM) FURFURACEA. Tubercles flattened at base (about 15 lines broad), triquetrous above, carinate beneath, the triangular terminal surface (about an inch broad by ½ inch) mamillate and (as also the lower surface) minutely furfuraceous-punctulate, the apex terminating in a suborbicular tomentulose areola (becoming naked): the centre a mass of silky-villous hairs, which persist in the axils of the tubercles: flowers 12 to 15 lines long, the inner petals (9 lines long) white or pinkish, the sepals brownish. — At Carneros Pass; September, 1889 (n. 2580).

PRIONOSCIADIUM WATSONI, Coulter & Rose, in herb. At the time of the description of this genus with its three species (Proc. Amer. Acad. 23. 275) the specimens of *Peucedanum Mexicanum* (l. c. 17. 361), from near San Luis Potosi, were overlooked. Examination shows this to be a fourth species, as has been noted in the Gray Herbarium by Prof. Coulter and Mr. J. N. Rose, who have named it as above. Fruiting specimens collected by Mr. Pringle near Guanajuato in 1888 (n. 2298) were distributed under this name, and it was again found by him in October, 1889, near the same locality (n. 3002). These are the same as Dr. Palmer's n. 275 from the same region, in very young fruit, which was unfortunately named at a venture *Cicuta* (?) *linearifolia* (l. c. 22. 415). It now appears that the species is very variable in its foliage, the leaflets ranging from elongated linear and serrate to lanceolate and laciniately dissected. The fruit also varies in the character of the epicarp, which is usually thin but sometimes quite corky. The vittæ are nearly contiguous about the seed.

PEUCEDANUM (?) MADRENSE. Acaulescent (?), glabrous; rootstock thick and branching, apparently perennial: basal leaves large, on long stout sheathing petioles, twice ternate or ternate-quinate; leaflets ovate, sharply serrate, more or less lobed, 1 or 2 inches long: rays about 12, an inch long or more: fruit oblong-ovate, 6 lines long

by 3 broad, rather strongly 3-ribbed on the back, the thin lateral wings as broad as the seed; commissural face usually more or less strongly 2–3-nerved, with 4 to 6 vittæ; dorsal vittæ 4, with some smaller intermediate ones: seed more or less deeply concave, somewhat channelled on the back beneath the broad vittæ. — In the Sierra Madre, near Monterey; June, 1888 (n. 2211). Differing from most American species in the more than usually channelled seeds, on both the ventral and dorsal sides, and in the nerved commissure.

RHODOSCIADIUM, n. gen. of Peucedanoid *Umbelliferæ*. Calyx-teeth minute. Stylopodium depressed-conical upon a rather prominent undulately margined disk. Fruit orbicular, flattened dorsally, and with broad thin lateral wings; dorsal ribs 3, thickened filiform, and often 2 shorter and much less prominent on each side of these; commissure strongly nerved in the middle; vittæ nearly contiguous about the seed, 8 on the commissure, the dorsal as many or more. Seed somewhat concave on the face. — Tall and slender, with pinnately compound leaves, small few-rayed umbels in nearly naked lateral and terminal panicles, and dull reddish flowers; involucres and involucels of a few linear bracts.

R. Pringlei. Glabrous throughout; cauline leaves ample, bipinnate with the divisions laciniately pinnatifid; those on the branches reduced to linear bracts dilated at base: rays 3 to 5, 3 to 5 lines long: fruit nearly sessile, 3 lines long. — On hillsides near Guadalajara; October, 1889 (n. 2981). The genus is peculiar in its habit, most nearly related in its fruit to *Tiedemannia*. The generic name has reference to the color of the flowers, and is also commemorative of the services of Mr. J. N. Rose, of Washington, who has done so much, in connection with Prof. Coulter, to elucidate the American representatives of the order.

Oreopanax Jaliscana. A small tree (20 feet high), with stout branches, rather sparingly furfuraceous- and stellate-pubescent: leaves cordate at base, 5-lobed to the middle, the lobes acute, mostly somewhat sinuately toothed or lobed, the petiole about equalling or shorter than the blade (4 to 10 inches broad): racemes in a broad open panicle (1 to 1½ feet broad); flowers in dense heads subtended by tomentose ovate bracts as long as, or exceeding, the ovaries: corolla spreading or calyptrately deciduous: filaments filiform: ovary 1–3-celled, with as many slender styles; fruit subglobose, 1–3-celled, black at maturity: albumen strongly ruminate. — In a barranca near Guadalajara; 1888 (n. 1822), and 1889 in fruit (n. 1889). Resem-

bling *O. Salvinii*, Hemsley, and like it peculiar in the reduced number of ovary-cells.

Gonzalea glabra. A small tree (20 feet high), glabrous throughout: leaves oblong-lanceolate, acute or acuminate, cuneate at base on a petiole about ½ inch long, entire, 2 to 4 inches long; stipules caducous: spike-like racemes slender, many-flowered, the pedicels very short: calyx campanulate, truncate or sinuate-dentate; corolla 1 or 2 lines long, with a broad tube and spreading rounded lobes, white or purplish: fruit unknown. — In the mountains near Lake Chapala; December, 1889 (n. 2442). Flowers fragrant.

Randia tomentosa. Branchlets armed at the extremity with four stout spreading spines 3 or 4 lines long: leaves narrowly ovate to oblong-ovate or oblanceolate, acute or acutish, attenuate below into a short petiole, tomentose both sides, greener above, 2 to 4 inches long: fruit terminal on the branchlets and sessile, pubescent, globose and short-stipitate, 1½ inches in diameter. — In the Sierra de la Silla, near Monterey; August, 1889 (n. 2865). Flowers unknown.

Crusea cruciata. Annual; stem simple, erect, few-jointed, compressed, sparsely retrorsely hispid on the angles, otherwise glabrous: leaves narrowly lanceolate, acuminate, 2 to 2½ inches long, the uppermost dilated and ciliate at base, as are also the similar but smaller floral bracts: flowers in most of the axils, the very short pedicels subtended by a circle of bristles; calyx-lobes triangular-subulate, a line long, nearly equal: fruit didymous, the cocci separating from a bifid axis, minutely and closely tuberculate, a line long or more. — Barranca near Guadalajara; October, 1889 (n. 2969).

Crusea villosa. Annual, erect, slender, about a foot high, sparingly branched, scabrous: leaves linear-oblanceolate, acuminate, ½ to 1½ inches long, the uppermost subtending a sessile dense rather few-flowered head; floral bracts large and rigid, dilated at base and copiously white-villous within, abruptly herbaceous-tipped: calyx-lobes 4, linear, less than a line long, about equalling the minute white corolla: fruit a line long, 2-coccous, somewhat compressed, the oblong-obovate cocci separating from a narrow linear axis. — On rocky hillsides near Guadalajara; October, 1889 (n. 2448).

Spermacoce Pringlei. Annual, erect, sparingly branched, about a foot high, glabrous nearly throughout: leaves oblong-ovate, acute, narrowed below to a short petiole, scabrous on the margin, 1½ inches long or less; stipules reduced to a row of slender bristles: flowers very small, in dense axillary clusters: fruit glabrous, less than a line long, oblong-elliptical, crowned by the small linear-subulate

erect calyx-teeth: seed smooth. — Shaded hillsides near Guadalajara; September, 1889 (n. 2464). With the habit of *S. glabra.*

JALISCOA; new genus of *Eupatoriaceæ.* Heads few-flowered. Involucres oblong-campanulate, its scales few, in two rows, nearly equal, narrowly oblong, strongly concave, scarcely nerved. Receptacle small, paleaceous, the caducous paleæ resembling the involucral scales and embracing the achenes. Corolla gradually dilated above the narrow base, 5-toothed. Anthers short-appendaged, obtuse at base. Style-branches somewhat papillose. Achenes glabrous, linear, 4-angled, the angles thickened and the truncate apex dilated. Pappus none. — Suffrutescent, erect and branched; leaves opposite at least on the branches, petiolate, dentate, sub-triply nerved; heads small, in terminal corymbs or corymbose panicles; flowers white.

J. PRINGLEI. Much branched and nearly glabrous, 6 to 8 feet high: leaves ovate to lanceolate, acuminate, cuneate at base, 2 to 4 inches long, minutely pubescent as well as the inflorescence: heads numerous, 1½ lines long, about 10-flowered, the exserted corollas as long. — Talus of cool ledges, bluffs of the Rio Grande de Santiago, Jalisco; October and November, 1889 (n. 2198 and 2491). The genus is near *Alomia* and *Aschenbornia,* distinguished especially by the narrow concave scales and chaff embracing the achenes.

AGERATUM (CŒLESTINA) CALLOSUM. Perennial, the herbaceous ascending stems about a foot high, floccose-pubescent throughout; branches spreading: leaves thin, ovate, rounded or subtruncate at base, acute, crenately serrate, 2 inches long or less, much exceeding the petioles: heads in small terminal corymbs; involucre 2 lines long, nearly glabrous, the narrow usually purplish scales 2–3-nerved below; receptacle nearly flat: corolla white, glabrous: achenes very small (scarcely ½ line long), slightly scabrous on the angles, with a prominent subglobose basal callus; pappus an entire cup-shaped crown with incurved margin. — On wet cliffs near Guadalajara; December, 1888 (n. 2166). With the habit of *A. conyzoides.*

HELIOPSIS FILIFOLIA. Herbaceous, branching from the base, glabrous, a foot high or more: leaves filiform, 2½ inches long or less, opposite and fascicled, the upper alternate: involucre broadly campanulate, slightly pubescent, the oblong nerved scales acutish: ligules elliptical, 3-toothed, 3 or 4 lines long: achenes glabrous, obtusely tetragonal, truncate, strongly tuberculate. — On limestone hills at Carneros Pass, Coahuila; September, 1889 (n. 2396).

ZALUZANIA RESINOSA. Tall and stout, the angled stem and branches loosely tomentose or glabrate: leaves broadly rhombic-

ovate (6 inches long by 4 broad) to lanceolate upon the branches, short-acuminate, narrowed at base to a short stout petiole, subcrenately serrate, roughish-puberulent above, thinly tomentose beneath and with numerous minute resinous globules: heads corymbose on short pedicels; outermost involucral scales herbaceous, the rest thin, elliptical, obtuse, many-nerved: rays 3 or 4 lines long: achenes large for the genus ($1\frac{1}{3}$ lines long). — In the Sierra Madre near Monterey; August, 1889 (n. 2412).

WYETHIA MEXICANA. Woody at base, 3 to 5 feet high, rather slender, rough-hispid: leaves thin, alternate, slenderly petiolate, ovate or the upper lanceolate, cordate or the upper rounded at base, short-acuminate, soft-tomentose beneath, scabrous and subpubescent above, 3 or 4 inches long: heads on axillary and terminal peduncles, $\frac{1}{2}$ inch high; involucre campanulate, of several rows of rather rigid-based bracts with long foliaceous acuminate tips: ray-flowers pistillate, numerous, the narrow ligules 9 lines long: achenes small (scarcely 2 lines long), obtusely quadrangular with the sides sulcate; pappus of several unequal acute or acuminate rigid persistent scales united at base. — Grassy foothills of the Sierra Madre near Monterey; June, 1888 (n. 1923). Rather abnormal in habit and involucre, but the achene, though small, and pappus are wholly those of the genus.

PERYMENIUM ALBUM. Suffrutescent, the branches hispidulous-scabrous: leaves rather narrowly lanceolate, very shortly petiolate, acuminate, rounded or cuneate at base, entire or sparsely serrulate, very scabrous above, pubescent beneath, 1 to $2\frac{1}{2}$ inches long: heads few in terminal corymbs and solitary on short lateral branchlets, the short stout peduncles pubescent; involucral scales lanceolate, acutish, pubescent: rays white, very broadly obovate, 2 lines long, crenately few-toothed: achene subtetragonal; pappus-bristles distinct. — In the mountains near Lake Chapala; December, 1889 (n. 2438).

CHRYSACTINIA TRUNCATA. Suffrutescent, low, much branched, the slender herbaceous branches short (2 or 3 inches), glabrous: leaves opposite or alternate, pinnately divided, the segments (1 to 3 pairs) cuneate, entire or with a lateral tooth, truncate, mucronate, the mucro bearing a prominent gland (the leaves otherwise glandless): peduncles terminal, short: involucral scales 12, two lines long: rays bright yellow: achenes, pappus, corolla, style-branches, etc., as in *C. Mexicana*. — Summit ledges of the Sierra de la Silla, Nuevo Leon; June, 1889 (n. 2601).

CHRYSACTINIA PINNATA. Glabrous throughout or nearly so; stems herbaceous, erect, slender, branching, a foot high or more:

leaves opposite, sparsely glandular-dotted, narrowly lanceolate, 1 to 2½ inches long, pinnately divided squarely to the midvein, the segments (4 to 10 pairs) acute, the lowermost usually much narrower: heads on slender peduncles; involucral bracts 8, three lines long: rays bright orange: flowers and achenes closely resembling those of *C. Mexicana.* — On limestone ledges of mountains near Monterey; May, 1889 (n. 2524). These species are certainly congeneric with *C. Mexicana*, though very different in habit.

Pectis (Pectothrix) bracteata. Perennial, the caudex much branched, with the habit of *P. longipes* but somewhat taller: leaves very narrow (almost filiform), 1 to 3 lines long, pungent, without setæ at the base and rarely with 1 or 2 lateral lobes: peduncles elongated, bracteate: involucre broad, the oblong scales (10 to 15) broadly thickened below: rays white: achene 1½ lines long, very finely striate and minutely tuberculate, hispidulous only at the base and summit; pappus of about 15 bristles, narrowly paleaceous toward the base. — On calcareous hills at Carneros Pass, Coahuila; September, 1888 (n. 2403).

Senecio Chapalensis. Soft-shrubby, resembling a *Pelargonium* in habit: leaves thin, long-petiolate, peltate (the petiole attached about ½ inch above the base), orbicular or subtriangular in outline, acutely 5–7-lobed with shallow obtuse sinuses, denticulate by excurrent veinlets, puberulent both sides, 4 inches broad or less: panicle puberulent, loose, the bracts lanceolate or oblanceolate to linear; peduncles slender, an inch long or less, straight: involucral bracts 8, 3 or 4 lines long: rays 5, bright yellow; corolla-lobes not half the length of the throat. — In the mountains near Lake Chapala; December, 1888 (n. 2419). This species closely resembles *S. subpeltatus*, Schultz Bip. (*Cacalia penduliflora*, Gray), of which it might be considered a radiate variety, but which is nearly or quite glabrous, with peltate bracts, more slender pendulous peduncles, and longer involucral scales. The corollas are the same in both.

Senecio Montereyana. Perennial (?) with a short branching rootstock, more or less densely white-floccose-tomentose throughout; stems slender, a foot high, naked above, bearing a few (4 to 6) long-peduncled heads: leaves mostly near the base, petiolate, 4 to 6 inches long by an inch wide, pinnately parted into numerous cuneate to oblong coarsely few-toothed lobes: involucre 3 lines long, tomentose, the scales narrowly acuminate: achenes finely pubescent. — On dry shaded ledges, near Monterey; June, 1888 (n. 1922).

Cacalia Pringlei. Tall and rather slender, glabrous or nearly so: radical leaves long-petiolate, ample, the blade (a foot long) broadly elliptical in outline, deeply pinnatifid with rounded sinuses, the 4 or 5 pairs of lobes again similarly pinnatifid, their few segments mostly coarsely toothed: bracts of the broad loose panicle narrowly lanceolate, entire or sparingly toothed: heads 3 or 4 lines long, about 12-flowered, the campanulate involucre of 8 broad acute bracts 2 or 3 lines long: corolla cleft nearly to the middle: achenes pubescent. — On grassy slopes of the barranca near Guadalajara; November, 1888 (n. 1749, 1811). The foliage is much as in *C. sinuata*, but the involucral scales are shorter and broader, and panicle much more open.

Cnicus Pringlei. Tall and slender, branched above: leaves greenish above, densely white-tomentose beneath; the lower a foot long or more, petiolate, deeply pinnatifid, the narrow segments with 1 to 3 lateral lobes, rather sparsely spinose with slender prickles; the upper sessile and clasping: heads small (about an inch long), solitary or in pairs; involucre nearly glabrous, the very unequal narrow scales with a prominent black viscid midvein, the lower with an appressed short spine, the upper with slightly rigid attenuate tips: corolla purple: anthers acutely appendaged. — In the Sierra Madre near Monterey; 1889 (n. 2507). Of the *C. altissimus* group, marked by the black scales without spreading setiform prickles.

Perezia grandifolia. Stout and tall (6 to 10 feet high), glabrous: cauline leaves thin, large (some a foot long by 8 inches broad), sessile with a broadly auriculate base, obovate, obtuse, sharply repand-serrulate; floral leaves small, oblong with auriculate base, acute: panicle broad, open, glandular-puberulent and viscid, the small 10–12-flowered heads (6 lines long) on slender peduncles: involucral scales herbaceous, linear-lanceolate, acuminate, in few series, passing downward into the bracts of the pedicel: achenes glabrous. — On cool rocky hillsides near Guadalajara; 1889 (n. 1858). Of the *P. Thurberi* group, as arranged by Dr. Gray.

Perezia capitata. Slender (5 to 8 feet high), widely branching, leafy, somewhat finely pubescent: leaves thickish, rigid, rhombic-ovate to lanceolate, acuminate, cuneate or the upper rounded at base, sessile or very nearly so but not at all amplexicaul or auriculate, the cauline 3 to 5 inches long by 1 to 3 broad: heads sessile in terminal clusters, 5-flowered, 4 or 5 lines long; involucral scales rather few, narrow, acuminate: achenes puberulent. — On warm rocky hillsides near Guadalajara; 1888 (n. 1859). With *P. Seemanni*, as grouped by Dr. Gray, but very different in habit and other characters.

TRIXIS HYPOSERICEA. Shrubby, slender, much branched, the branchlets finely pubescent: leaves linear-lanceolate (2 or 3 inches long by 3 or 4 lines broad), attenuate above, narrowed below to a short petiole, entire, green and nearly glabrous on the upper surface, appressed silky-villous beneath: inflorescence very open, the heads on slender nearly naked peduncles; involucre of 8 finely pubescent acutish scales in one row, 4 lines long, with 2 or 3 short linear spreading bractlets at base: receptacle very villous: achenes densely puberulent. — In the barranca near Guadalajara; 1888 (n. 1741).

LOBELIA SUBLIBERA. Biennial (?), erect and branching, 1 or 2 feet high, very finely roughish-pubescent: early radical leaves ovate to elliptical, glandular-serrulate, the cauline distant, linear-lanceolate, acuminate, acute at base, sparingly denticulate: racemes long-pedunculate, mostly few-flowered, secund; bracts very small, linear; pedicels 2 to 6 lines long: calyx-tube almost none, the linear-acuminate lobes (2 lines long) upon a very abrupt base: corolla blue, with tube 5 lines long, and the broad lobes of the limb rounded and obtuse: capsule free from the calyx excepting the very short acute base, ovate, 3 lines long. — On cool shaded slopes of the Sierra Madre near Monterey; July, 1888 (n. 1889).

LOBELIA PRINGLEI. Stems numerous from an apparently perennial rootstock, branching at base and leafy below, finely pubescent throughout: leaves ovate, acutish or the lowest very obtuse, the margin slightly sinuate or entire, 6 to 9 lines long, about equalling the winged petiole: peduncle naked, bearing a loose rather few-flowered raceme (a foot high); bracts linear; lower pedicels about an inch long: calyx turbinate, about half the length of the linear lobes, which equal the tube of the blue corolla (3 or 4 lines long). — On limestone ledges near Monterey; June, 1889 (n. 2538).

CLETHRA PRINGLEI. A tree 25 to 40 feet high: leaves oblanceolate, acuminate, obtuse at the narrow base, entire or sparsely serrate, glabrous above, tomentulose beneath, 3 or 4 inches long by 1 to $1\frac{1}{2}$ broad, short-petiolate: inflorescence a terminal sessile racemose panicle, hoary-tomentulose throughout; racemes slender, elongated (4 to 6 inches long); pedicels slender, 3 or 4 lines long: flowers small; sepals acuminate, $1\frac{1}{2}$ lines long; petals roundish, shortly fimbriate: style equalling the calyx. — In the mountains east of San Luis Potosi; June, 1890 (n. 3098).

FORESTIERA TOMENTOSA. Branches and leaves (especially beneath) densely tomentose: leaves entire, subcoriaceous, oblong-ovate, cuneate at base, acutish or obtuse, 9 to 12 lines long, very shortly

petiolate: pedicels umbellately clustered, 2 to 4 lines long: drupes narrowly oblong, curved, rounded at base, 3 to 5 lines long. — Hills near Guadalajara; May, 1889, in fruit only (n. 3021). Near *F. pubescens,* but with thicker and more tomentose entire leaves and with longer and more oblong curved drupes.

FORESTIERA RACEMOSA. A tall evergreen shrub or small tree (10 to 20 feet high), forming clumps: leaves rather thin, ovate to lanceolate, acute or short-acuminate, acutish at base, entire or serrulate, puberulent above and thinly tomentose beneath or glabrate, 9 lines to 2 inches long, on slender petioles 2 or 3 lines long: flowers pedicelled, opposite in very short racemes (the fertile racemes about 6 lines long in fruit); calyx of pistillate flowers minute, persistent: fruit globose, 2 to 2½ lines in diameter; putamen smooth. — At the base of the Sierra Madre near Monterey; August, 1889 (n. 2394).

METASTELMA MULTIFLORUM. Glabrous or nearly so (the petioles and inflorescence somewhat pubescent): leaves linear to linear-lanceolate, acuminate, obtusish at base, shortly petiolate, 6 to 10 lines long or usually less, much reduced on the branches: flowers clustered in most of the axils, a line long, the pedicels mostly shorter than the calyx: calyx-lobes short, acute; corolla greenish white or tinged with purple, the oblong acute lobes puberulent within: column as long as the anthers; lobes of the crown inserted at the base of the anthers, linear-lanceolate, exceeding the stigma. — Twining over shrubs in ravines near Guadalajara; November, 1888 (n. 1776). Allied to *M. Schaffneri* and *M. angustifolium.*

MARSDENIA PRINGLEI. Somewhat puberulent: leaves nearly glabrous, oblong-ovate, acute or abruptly short-acuminate, obtuse at base, 2 to 4 inches long, on petioles 6 to 12 lines long: peduncles a little shorter than the petioles, few–many-flowered, the pedicels 1 to 3 lines long: sepals ovate; corolla white, 3 or 4 lines long, cleft to below the middle, glabrous: divisions of the crown distinct, tipped with a broad triangular appendage slightly exceeding the broad obtuse and entire tip of the anther: stigma terminated by a long-exserted attenuate beak, bifid at the apex, 2 lines long: fruit unknown. — In the Sierra de la Silla, near Monterey; June, 1889 (n. 2531).

OMPHALODES MEXICANA. Stems procumbent, from a perennial branching rootstock; canescent throughout with fine spreading pubescence: leaves ovate, acute, subtruncate or subcordate at base, 3 to 8 lines long, shorter than the petioles; floral bracts more or less cuneate at base and mostly sessile: pedicels elongated (6 to 12 lines), in long terminal racemes: corolla white (3 lines broad), with very

prominent erect appendages at the throat: lobes of the ovary nearly horizontal upon the broad flattish gynobase; only 1 or 2 nutlets usually maturing, attached by a broad ovate scar from above the base to near the apex, round-ovate, 1½ lines long, the marginal wing strongly involute, denticulate. — In fissures of dry limestone rocks in the Sierra Madre near Monterey; June, 1888 (n. 1878). Evidently a congener of the plants collected by Dr. Palmer in the same region and referred to this genus by Dr. Gray (*O. aliena* and *cardiophylla*).

BRACHISTUS PRINGLEI. Shrubby (?) with herbaceous virgate branches, finely pubescent throughout: leaves mostly geminate, ovate to lanceolate, acute or short-acuminate, rounded at base on a short margined petiole, 1 to 2½ inches long, one of the pair much smaller: pedicels solitary or in pairs in the axils, about 6 lines long: calyx small, truncate, with a linear tooth at each angle as long as the tube; corolla campanulate, plicate-angled, 3 lines long: fruit depressed-globose, 2 or 3 lines broad. — In the Sierra de la Silla near Monterey; May, 1889 (n. 2544).

BERENDTIA SPINULOSA. Shrubby, with rigid branches, the upper branchlets developing into short spines, leafy, finely glandular-hispid throughout: leaves oblanceolate or oblong-oblanceolate, acute or acutish, cuneate at base and sessile or nearly so, entire or sparingly toothed, 9 lines long or less: pedicels mostly solitary in the upper axils, about equalling the leaves: calyx 3 lines long, with short acute teeth; corolla yellow, ½ inch long, with ample limb: anthers very small: capsule lanceolate, 2 lines long — On dry limestone cliffs of the Sierra Madre near Monterey; June, 1888 (n. 1952). Near *B. Coulteri.*

GRATIOLA (SOPHRONANTHE) MEXICANA. Annual, slender, loosely branching, 3 or 4 inches high, glabrous or nearly so: leaves oblong-ovate, acute, spreading, 2 lines long or less: pedicels naked, 1½ to 3 lines long: calyx-segments nearly equal, narrowly lanceolate, about equalling the oblong capsule (a line long); corolla purple, 2 or 3 lines long: anther-cells contiguous but transverse; sterile filaments papillose-pubescent: seeds very minute. — In shallow water on the plains of Guadalajara; October, 1889 (n. 2468). This species has the contiguous anther-cells of the section, but varies from it in their transverse position and in the longer ebracteolate pedicels.

ISOLOMA JALISCANUM. Stems herbaceous or somewhat woody at base, decumbent, about a foot high, pubescent throughout: leaves opposite, oblong-lanceolate, short-acuminate, rounded or acutish at base, serrate, 1 to 3 inches long, shortly petiolate: peduncles axillary,

½ to 1 inch long, bearing an umbel of 2 to 4 flowers on pedicels becoming ½ to 1½ inches long: calyx-lobes acuminate, 4 to 6 lines long in fruit; corolla an inch long, scarlet, pubescent, nearly straight, cylindric-funnelform, moderately dilated upward and the throat but little contracted: capsule turbinate-oblong, included. — On the Rio Blanco, Jalisco; 1888 (n. 1828); also collected by Dr. Palmer in 1886 (n. 577).

Beloperone Pringlei. Erect, pubescent, somewhat branched: leaves ovate-lanceolate, acutish, cuneate at base, short-petiolate, 1 or 2 inches long or smaller on the branches: spikes axillary and terminal, on very short peduncles, dense and imbricately bracteate, ½ to 1½ inches long; bracts foliaceous, sessile, about ½ inch long or more: calyx-segments narrowly lanceolate, unequal, the longer 4 lines long and about equalling the capsule: corolla yellow (?), narrowly tubular, 12 to 15 lines long, the narrow lips slightly cleft: seeds flattened. — Hills near Monterey; July, 1889 (n. 2548).

Priva armata. Low and slender, a foot high or less, much branched from the base, roughish hispid-pubescent throughout: leaves sessile, ovate, acute, coarsely and irregularly toothed and somewhat lobed, 9 lines long or less: spikes few-flowered, short and leafy-bracteate: corolla 3 or 4 lines long, the tube equalling the calyx: fruiting calyx subglobose, 3 lines in diameter, loosely enclosing the fruit, which is covered with stout straight spines. — Valley of Monterey; July, 1888 (n. 1931).

Poliomintha bicolor. Much branched, forming low dense clumps: leaves linear, or narrowly oblong (2 to 4 lines long) on short slender petioles, white beneath (as the branches and calyx) with a compact puberulence, glabrous and porulose above: calyx-teeth equal, erect; corolla 15 lines long, the very narrow tube pubescent within toward the base: sterile filament very short and rudimentary. — On summit ledges of the Sierra de la Silla, at 5,000 feet altitude; June, 1889 (n. 2536). Resembling *P. Greggii*, but without loose pubescence and the leaves narrower.

Scutellaria suffrutescens. Woody below, much and widely branched, about 6 inches high, the branches very finely puberulent: leaves entire, oblong-ovate, obtuse, shortly petiolate, 3 to 5 lines long: flowers solitary in the upper axils, on short pedicels: corolla pubescent, narrowly tubular, 9 lines long, greenish yellow and more or less tinged (especially the suberose lower tip) with red. — On the bare summit of the Sierra de la Silla, near Monterey, at 5,000 feet altitude; June, 1889 (n. 2535).

Iresine Pringlei. Shrubby, finely tomentose, diœcious: very young leaves densely white-tomentose, becoming bright green and nearly glabrous above and thinly tomentose beneath, lanceolate, acute or acutish, subcuneate at base, short-petiolate, 2 or 3 inches long: inflorescence a broad open naked panicle, the small sessile clusters thickly scattered along the branches, often contiguous: bracts of staminate flowers very minute, the hyaline sepals linear-oblong; bracts of pistillate flowers broadly ovate, very thin, shorter than the calyx; sepals rigid, very woolly especially near the base, about ½ line long, lanceolate, acuminate and the tips somewhat spreading, with a broad bright green midnerve and white margins. — On shaded ledges of the barranca near Guadalajara; November, 1888 (n. 1785). A species well marked by the peculiar calyx of the fertile flowers.

Euphorbia (Chamæsyceæ) longeramosa. Of the *Leiospermæ* group, annual, glabrous, the divaricate branches often 2 or 3 feet long: stipules lanceolate, laciniately cleft; leaves linear, obtuse at both ends or cuneate at base, very shortly petiolate, 6 to 15 lines long: involucres solitary in the axils or somewhat cymose, on mostly very short peduncles, broadly campanulate, a line long; lobes erect, triangular, acute or apiculate, entire; glands transversely oblong, with an erect yellowish broad reniform appendage: capsule small, acutely lobed, smooth: seed subcompressed-triangular. — On sand hills near Samalayuca, Chihuahua; September, 1889 (n. 2000).

Euphorbia (Zygophyllidium) hexagonoides. Annual, slender, erect and branching, glabrous throughout or the involucres and floral leaves slightly pubescent: leaves all opposite, very narrowly linear, attenuate at each end and long-petiolate, ½ to 1½ inches long: involucres very small, the lobes scarious, quadrate, lacerate-dentate; glands purplish, incurved, with a horizontal deltoid appendage (sometimes very small or none): capsule with broad rounded lobes: seed a line long, ecarunculate, subtetragonal, acute, strongly and irregularly tuberculate. — On dry banks in the foothills of the Sierra Madre, Nuevo Leon; October, 1889 (n. 2016). Near *E. hexagona*.

Euphorbia (Esulæ) longecornuta. Perennial, woody below, much branched, 6 inches high or more, glabrous and glaucous: leaves numerous, oblong to broadly elliptical, acute or acutish and mucronate, about 3 lines long: rays 3 to 5, short (½ inch), simple or once branched, the bracts like the cauline leaves or broader: involucres small (less than a line long), about equalling the peduncle; glands usually with long-attenuate horns nearly as long as the involucre; lobes oblong, densely ciliate: seeds coarsely and irregularly few-

pitted. — In crevices of cliffs at the summit of the Sierra de la Silla, at 5,000 feet altitude; June, 1889 (n. 2545). With wholly the habit of forms of *E. campestris,* differing in the smaller involucres, longer-appendaged glands, and in the seeds.

ACALYPHA DIOICA. Woody at base and apparently perennial, the erect stems sparingly branched, 1 or 2 feet high, finely pubescent, the pubescence on the upper surface of the leaves short-villous and subappressed: leaves ovate-lanceolate, short-acuminate, rounded at base, rather coarsely crenate-serrate, 1 or 2 inches long, on petioles 3 or 4 lines long: flowers diœcious (or the fertile spikes bearing only a rudimentary staminate flower at the apex); spikes all axillary, the staminate slender (1 to 1½ inches long), dense, long-pedunculate, the fertile nearly sessile, loosely few- (3–8-) bracteate; bracts reniform, 5–7-toothed, 1–2-flowered: capsule pubescent: seed globose, nearly smooth. — On limestone ledges near Monterey; June, 1889 (n. 2417). Resembling *A. glandulosa,* Cav., but the pubescence not at all glandular.

NEMASTYLIS BRUNNEA. Bulb dark-coated, 6 to 8 lines in diameter: stem nearly a foot high, bearing a single leaf 6 inches long, sheathing below and plaited above, and a concave sheathing acuminate bract subtending and equalling the peduncle; spathe several-flowered, 2½ inches long: perianth maroon-color or brownish purple, 6 lines long, the outer segments obtuse, the inner as long and similar, but acuminate and tipped with yellow: stamineal column a line long or more, the yellow anthers (2½ lines long) with a broadish connective: style-branches scarcely shorter, cleft nearly to the base, stigmatic half their length, bearing a filiform purple appendage in the sinus. — Described from flowering plants raised from bulbs collected near Guadalajara in 1889.

ZEPHYRANTHES ERUBESCENS. Bulb ovate, dark-coated, over an inch in diameter, the neck as long: leaves about six, 6 to 15 inches long by 2 or 3 lines broad, concave, not carinate, glaucous: scape 6 inches high; spathe tubular, bifid above, the tube equalling and closely embracing the pedicel (about an inch long): perianth 2 inches long, rather narrowly funnelform, white strongly tinged with rose-color without, the tubular base greenish: filaments very short, inserted on the throat, the slender anthers (3 lines long) exceeding the shortly lobed stigma. — Locality uncertain, but probably from sandy plains in Duval County, Texas, — perhaps northern Mexico; 1888. Described from plants in flower at Cambridge, August, 1889. Near *Z. Lindleyana.*

Agave (Littæa) vestita. Leaves very numerous, stiff, straight, ensiform, a foot long or less, by 6 or 8 lines broad, flat above, convex beneath, attenuate to a very pungent brown tip, covered throughout when young with a thin white continuous layer which is at length deciduous, leaving a smooth green surface variegated with scattered round lighter-colored spots, the margin bordered by long gray recurved threads: flowers sessile in pairs; ovary and narrowly turbinate tube each 4 lines long, the narrow segments of the perianth 6 lines long: filaments twice as long: capsule broadly oblong, 6 lines long. — On porphyritic ledges near Guadalajara; November, 1889 (n. 2432).

Xyris Mexicana. Leaves linear, straight, 3 to 6 inches long by 1 or 2 lines broad, exceeding the sheathing bracts of the culm, which is very slender, terete, flattened above: head globose or ovate, 3 to 5 lines long, rather few-flowered, the orbicular bracts greenish brown, becoming nearly black: lateral sepals linear, long-attenuate downward, ciliolate above on the nearly wingless keel, equalling the bract; blade of the petals obovate, 3 lines long: sterile stamens plumose: capsule cuneate-obovate. — Swampy places near Guadalajara; Dr. E. Palmer, September, 1886 (n. 445), and C. G. Pringle, November, 1888 (n. 1781). Most nearly resembling *X. flexuosa*, but differing in its dark-colored heads and longer unguiculate sepals.

X.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

THE REACTIONS OF SODIC ALCOHOLATES WITH TRIBROMDINITROBENZOL AND TRIBROMTRINITROBENZOL.

By C. Loring Jackson and W. H. Warren.

Presented May 27, 1890.

We were induced to take up this piece of work — although at first sight it might seem to promise little of interest, either in the new compounds formed or in the nature of the reaction — by some experiments in a previous research which apparently indicated that one of the atoms of bromine in tribromdinitrobenzol would be replaced by hydrogen under the influence of sodic ethylate. If this was the case, the work would supply additional material on which to found an explanation of the substitution of bromine by hydrogen in the formation of bromdinitrophenylmalonic ester and allied compounds, described in several previous papers * from this Laboratory. Not only has the promise of these experiments been fulfilled, but the work has surpassed in interest all that we expected of it, as it has shown that sodic alcoholates (under which name we class phenolates also) act on tribromdinitrobenzol and tribromtrinitrobenzol in four different ways: —

First. A simple replacement of each atom of bromine by the radical of the alcoholate. This we have observed only in a single case, the action of sodic phenolate on tribromtrinitrobenzol giving trinitrophloroglucine triphenylether, $C_6(NO_2)_3(OC_6H_5)_3$, melting point 175°.

Second. The replacement of two atoms of bromine by two of the radical of the alcoholate, the third atom of bromine remaining unaltered. Under this head come the actions of sodic ethylate in the cold,

* These Proceedings, xxiv. 1, 256, 271, 288, 306 (1888–89).

methylate (in part), and phenolate on tribromdinitrobenzol, giving $C_6HBr(C_2H_5O)_2(NO_2)_2$, melting point 184°, $C_6HBr(CH_3O)_2(NO_2)_2$, melting point 237°–238°, and $C_6HBr(C_6H_5O)_2(NO_2)_2$, melting point 165°.

Third. The replacement of two atoms of bromine by the radical of the alcoholate, and the third by hydrogen. Sodic ethylate when hot, and sodic methylate (in part) whether cold or hot, act in this way on tribromdinitrobenzol, giving $C_6H_2(C_2H_5O)_2(NO_2)_2$, melting point 133°, and $C_6H_2(CH_3O)_2(NO_2)_2$, melting at 167°. These substances can also be made by boiling the corresponding bromine compounds (mentioned under the second class) with the proper alcoholate.

Fourth. The replacement of one, two, or perhaps three of the nitro groups by the radical of the alcoholate, the three bromine atoms remaining unaffected. This very strange action was observed with sodic ethylate or methylate and tribromtrinitrobenzol, giving $C_6Br_3C_2H_5O(NO_2)_2$, melting point 147°, $C_6Br_3(C_2H_5O)_2(NO_2)$, melting point 101°, and $C_6Br_3(CH_3O)_2(NO_2)$, melting point 126°.

The product of further action of sodic ethylate when hot, on tribromnitroresorcine diethylether has not yet been obtained in a state of purity, but we hope to be able to describe it in a later paper.

We have little to say in general about these different modes of action of the alcoholates, except to connect them with previous observations of a similar character, as we think that the number of facts established is still insufficient for the safe foundation of a theoretical explanation of these differences. We hope to continue the work, however, until such a foundation has been secured. The formation of the trinitrophloroglucine triphenylether (described under the first head) is analogous to the formation of trinitrophenylenedimalonic ester from the bromtrinitrophenylmalonic ester,* since in the corresponding dinitro compounds the third atom of bromine cannot be replaced by the phenoxy (see second head) or malonic ester radical, as the case may be, even under more powerful inducements than are needed to bring about this action with the trinitro compounds, thus furnishing another example of the loosening effect of the presence of a third nitro group upon the bromine. The stability of the third atom of bromine in the dinitro compound, so far as replacement by an alcoholate radical is concerned, mentioned under the second head, is analogous to that of the third bromine atom in dinitrobromphenylmalonic † or acetacetic ‡ ester in the corresponding

* These Proceedings, xxiv. 268. † Ibid., 2. ‡ Ibid., 274.

dinitrodibrom compound,* and to a less extent in the trinitro derivative †; while the replacement of bromine by hydrogen, mentioned under the third head, corresponds closely to the removal of the second atom of bromine from all these substances. In regard to the replacement of the nitro groups instead of the atoms of bromine by ethoxy or methoxy radicals, described under the fourth head, we can only say that the conditions were essentially the same as those under which the bromine in the dinitro compound was replaced, and that as yet we have no hint of an explanation for it, but hope that future experiments will throw some light on the cause of this strange behavior. We may here call attention to the fact, that the replacement of these nitro groups is in direct contradiction to Laubenheimer's rule,‡ that a nitro group is removed only when it is in the ortho position to another nitro group, since in the tribromtrinitrobenzol the three nitro groups are in the meta position to each other. Whether this exception to Laubenheimer's rule is due to the fact that it does not apply to sodic ethylate, or to some cause peculiar to the tribromtrinitrobenzol, must be determined by future experiment.

We also found that neither sodic acetate nor sodic picrate acted on tribromdinitrobenzol even at 100°, nor did sodic picrate act on tribromtrinitrobenzol, which justifies the inference that decidedly acid radicals cannot be taken up by these molecules, which contain so many nitro groups. Also we have repeated the experiment on the action of malonic ester upon tribromdinitrobenzol and confirm the negative results previously obtained.§

The description of the experimental details of the research occupies the rest of the paper.

Action of Sodic Ethylate on Tribromdinitrobenzol in the Cold.

In order to study this action 20 gr. of tribromdinitrobenzol (melting point 192°, made from symmetrical tribrombenzol) dissolved in a mixture of 40 c.c. of benzol and 90 c.c. of absolute alcohol were treated with an alcoholic solution of the sodic ethylate, made from 3.4 gr. of sodium, which gave the proportion of three molecules of sodic ethylate to one of tribromdinitrobenzol. That a reaction took place was indicated by the appearance of a pale reddish yellow color, which gradually increased in intensity to a dark brownish red, but there was no perceptible evolution of heat. To give the reaction

* These Proceedings, xxiv. 294.

† Ibid., 258.

‡ Ber. d. ch. G., ix. 766, 1828.

§ These Proceedings, xxiv. 308 (1889).

time to run to an end, the mixture was allowed to stand in a corked flask at ordinary temperatures for two or three days, and then was filtered to remove a considerable amount of solid matter which had separated, and the filtrate allowed to evaporate spontaneously. The solid remaining on the filter was washed with water to remove sodic bromide, the presence of which was proved by testing this wash water with argentic nitrate after acidification with nitric acid, and the portion insoluble in water added to the main product when that had been brought to the same degree of purity. This main product was deposited from the filtrate by the spontaneous evaporation of the solvent, and after washing with water was purified by crystallization from hot alcohol until it showed the constant melting point 184°. It is worth mentioning that the earlier crystallizations yielded round woolly masses of fine needles, which were gradually converted, as the substance approached purity, into well formed prisms or plates, since this change in the crystalline habit furnishes a convenient indication of the comparative purity of the substance. The analyses of the substance dried at 100° gave the following results: —

I. 0.2616 gr. of the substance gave on combustion 0.3426 gr. of carbonic dioxide and 0.0904 gr. of water.

II. 0.2753 gr. of the substance gave 21.9 c.c. of nitrogen at a temperature of 25° and a pressure of 745.5 mm.

III. 0.1830 gr. of the substance gave according to the method of Carius 0.1032 gr. of argentic bromide.

	Calculated for $C_6HBr(C_2H_5O)_2(NO_2)_2$.	Found. I.	II.	III.
Carbon	35.83	35.72		
Hydrogen	3.28	3.84		
Nitrogen	8.36		8.70	
Bromine	23.89			24.00

There can be no doubt, therefore, that this substance melting at 184° is the bromdinitroresorcine diethylether formed by the replacement of two atoms of bromine by two of the ethoxy radicals.

The yield of bromdinitroresorcine diethylether is far from good, 20 gr. of tribromdinitrobenzol giving in no instance more than 4.6 gr. of this substance instead of the 16.5 gr. required if the whole of the tribromdinitrobenzol had been converted into it, that is, about 28 per cent; and, in fact, the alcoholic mother liquors from its purification yielded on evaporation a viscous residue in large quantity, our unsatisfactory work upon which will be described after the statement of the properties of the bromdinitroresorcine diethylether. We may

give here, however, the result of a determination of the amount of sodic bromide formed in the reaction. 5 gr. of tribromdinitrobenzol were treated in the cold with the sodic ethylate from 0.9 gr. of sodium in the manner described above, and, after the reaction had come to an end, water was added, the benzol solution removed, and the water extracted three times with benzol, after which it was made up to a volume of 500 c.c., and the amount of sodic bromide determined in 20 c.c. of this solution; the weight thus obtained calculated on the whole solution gave the result given below as found. The calculated number is the amount of sodic bromide which would be formed if two of the atoms of bromine in the tribromdinitrobenzol had been removed.

	Calculated.	Found.
Sodic Bromide	1.271 gr.	1.194 gr.

These results agree as closely as could be expected considering the unavoidable losses in extracting with benzol, and prove that in this case two of the atoms of bromine contained in the tribromdinitrobenzol were removed as bromide of sodium.

Properties of Bromdinitroresorcine Diethylether,
$C_6HBr(C_2H_5O)_2(NO_2)_2$.

The substance crystallizes from alcohol in rather thick flattened needles of a yellowish white color, which may attain a length of 1 cm. and sometimes a breadth of 1 mm. The ends are usually square, but less often consist of two planes at a very obtuse angle to each other. The larger crystals seem to be made up of needles united longitudinally, since their ends are apt to be sharply serrated, or even as much indented as the teeth of a comb. Crystallized from benzol it formed long slender prisms, sometimes reaching a length of 2 cm., terminated by two planes at an acute angle to each other, and efflorescing on exposure to the air. They showed however the same melting point as the crystals obtained from alcohol, and when recrystallized from this solvent gave the plates with square ends described above; they probably contained benzol of crystallization, which escaped before the temperature had risen to the melting point of the substance. It melts at 184°; and is not very soluble in alcohol even when hot, less so when cold; slightly soluble in methyl alcohol; nearly insoluble in cold water, very slightly soluble in hot; freely soluble in acetone; soluble in benzol or chloroform; slightly soluble in ether or glacial acetic acid; nearly insoluble in carbonic disulphide; and insoluble in ligroine. Alcohol, or alcohol with a little benzol, is

the best solvent for it. Neither sulphuric, nitric, nor hydrochloric acid has any apparent action on it, whether cold or hot.

As has been already stated, the alcoholic mother liquors from the crystallization of the bromdinitroresorcine diethylether yielded on evaporation a semi-liquid mass of most uninviting properties in considerable quantity; but although we have given much time to the study of this product, we are unable to make any definite statement in regard to its nature, and have not thought it worth while to postpone the printing of this paper until we could overcome the difficulties in its purification, as it does not lie in the direct line of our research, the principal object of which has been reached by our work on the bromdinitroresorcine diethylether and its derivatives. We think it well, however, to give a brief statement of our work on this secondary product, since we have succeeded in isolating a crystalline substance from this viscous mixture by a process of liquation, which we think will prove of value to those chemists who have similar mixtures to deal with. The viscous mass after standing for some weeks solidified, but even then was deposited from all its solutions in its original oily condition, and as therefore it could not be crystallized directly we proceeded as follows. Having found that about one quarter of it melted at 50°–60°, we placed it on several layers of filter paper in a dish heated to about 70° by means of a water bath, and allowed it to stand at this temperature for several days, renewing the filter paper as it was necessary, and toward the end of the process applying a gentle pressure. The less fusible residue thus obtained could now be crystallized from alcohol, and yielded a small quantity of a substance melting near 170°, which we took to be impure bromdinitroresorcine diethylether, but the amount was so small that we could not recrystallize it often enough to raise the melting point to the proper temperature, 184°. The principal part of this less fusible portion melted in the neighborhood of 150°, and proved to be a mixture which, to judge by the melting point, was the same as an abnormal product occasionally obtained from the process for making bromdinitroresorcine diethylether instead of that substance, although we could find no difference in the conditions of the process from those when it gave the normal result. We have not succeeded in separating this mixture into its components, as after several unsuccessful experiments the amount remaining at our disposal was too small to continue with any prospect of success the crystallizations, which seemed to purify it very slowly, as they had but little effect on the melting point. Some analyses of the mixture showed that it contained less carbon and more bromine than bromdinitroresorcine diethylether.

The more fusible portion of the secondary product, which had been absorbed by the papers in the process of liquation, was extracted with alcohol, and the oil thus obtained allowed to stand until it had nearly solidified again, when it was submitted to a second liquation, the more fusible product of which did not solidify, but only deposited a few crystals. As there were only about 10 gr. of this in all, and it manifestly contained two, and in all probability three or more substances we thought there would be little chance of isolating a pure compound from it, and accordingly, after one or two attempts to separate it into its components, its further study was abandoned.

Action of Sodic Ethylate on Tribromdinitrobenzol with the Aid of Heat.

As has been shown in the preceding section, sodic ethylate acting on tribromdinitrobenzol (melting point 192°) in the cold converts it into bromdinitroresorcine diethylether melting at 184°; but if, instead, the two substances are heated together, a different product is obtained which we have found it most convenient to prepare in the following way.

A solution of 10 gr. of tribromdinitrobenzol (melting point 192°) in 20 c.c. of benzol was mixed with the alcoholic solution of sodic ethylate formed from 45 c.c. of alcohol and 1.7 gr. of sodium, giving the proportion of three molecules of the ethylate to one of the tribromdinitrobenzol, and the mixture was heated on the steam bath to gentle boiling for about ten minutes in a flask under a return condenser. Longer or more violent heating should be avoided, as in this case a decomposition sets in, probably due to the action of the sodic ethylate on the nitro groups, which increases the difficulty in purifying the product. During the boiling the red color of the solution steadily increased in intensity, and a considerable amount of sodic bromide was deposited together with a brown amorphous substance which added to the turbidity of the reddish brown liquid finally obtained. A curious odor was also observed in the solution, which seemed to be characteristic of all the reactions in which bromine was replaced by hydrogen, and was probably due to the secondary product formed from the sodic ethylate, but did not smell like the aldehyd which we had supposed would be this secondary product by the following reaction: —

$$C_2H_5ONa + C_6HBr(C_2H_5O)_2(NO_2)_2 = NaBr + C_6H_2(C_2H_5O)_2(NO_2)_2 + C_2H_4O.$$

At the end of the ten minutes the solution was poured into an evaporating dish and allowed to evaporate to dryness spontaneously, washed with water to remove sodic bromide, and the reddish brown substance insoluble in water purified by crystallization from alcohol with the aid of boneblack until it showed the constant melting point 133°, when it was dried at 100°, and analyzed with the results given under I. and III. More than a year ago G. D. Moore with one of us obtained under somewhat different conditions the same substance as shown by the melting point and crystalline form, and we therefore add the analyses made of it by Dr. Moore at that time, II., IV., and V.

I. 0.2200 gr. of the substance gave on combustion 0.3752 gr. of carbonic dioxide and 0.0950 gr. of water.

II. 0.2320 gr. of the substance gave 0.3990 gr. of carbonic dioxide and 0.0995 gr. of water.

III. 0.2112 gr. of the substance gave 21 c.c. of nitrogen at a temperature of 26° and a pressure of 754.8 mm.

IV. 0.2299 gr. of the substance gave 22.3 c.c. of nitrogen at a temperature of 23° and a pressure of 762.2 mm.

V. 0.2142 gr. of the substance gave 20.3 c.c. of nitrogen at a temperature of 22°.5 and a pressure of 767 mm.

	Calculated for $C_6H_2(C_2H_5O)_2(NO_2)_2$.	Found. I.	II.	III.	IV.	V.
Carbon	46.88	46.50	46.90			
Hydrogen	4.69	4.80	4.77			
Nitrogen	10.94			10.96	10.96	10.81

It contained no bromine.

These analyses prove that the substance is the dinitroresorcine diethylether which must have been formed from the tribromdinitrobenzol $C_6HBr_3(NO_2)_2$ by the replacement of two of its atoms of bromine by two ethoxy radicals (C_2H_5O), the third by hydrogen, and we have here another case of the curious replacement of bromine by hydrogen in preference to its replacement by a radical combined with sodium, which was first observed in the study of the action of sodium malonic ester upon tribromdinitrobenzol, and which induced us to undertake the present investigation. Since this dinitroresorcine diethylether melts at 133°, it is isomeric with the one * already known melting at 75°.

* Aronheim, Ber. d. ch. G., xii. 32.

Properties of Dinitroresorcine Diethylether, $C_6H_2(C_2H_5O)_2(NO_2)_2$. —This substance crystallizes by cooling from an alcoholic solution in long slender needles or flattened prisms with a sharp point. If the alcoholic solution is allowed to evaporate spontaneously, it forms some curling hair-like crystals which are very characteristic. The crystals from alcohol are also apt to form clumps of radiating hairs shaped somewhat like a toadstool, especially if the substance is not absolutely pure. From ether it crystallizes in needles combined longitudinally into prisms with prickly ends; from chloroform, in radiating needles. It melts at 133°, and is nearly insoluble in water, although apparently a little more soluble in it hot than cold; not very soluble in cold alcohol, freely in hot; more soluble in methyl than in ethyl alcohol, whether cold or hot; freely soluble in chloroform, glacial acetic acid, or acetone; soluble in benzol; slightly soluble in ether; very slightly in carbonic disulphide; essentially insoluble in ligroine. Alcohol is the best solvent for it. Strong sulphuric acid dissolves it in the cold, forming a yellow solution; strong nitric acid has no action on it when cold, but gives a colorless solution if heated with it; strong hydrochloric acid has no action on it, whether hot or cold.

Conversion of Bromdinitroresorcine Diethylether into Dinitroresorcine Diethylether.

It has been shown in the two preceding sections that the action of sodic ethylate on tribromdinitrobenzol differs according to the conditions under which it takes place, since in the cold bromdinitroresorcine diethylether is formed, but when the mixture is heated the third atom of bromine is also removed and replaced by hydrogen, so that the product is the dinitroresorcine diethylether. In order to throw more light on this substitution of hydrogen for the third atom of bromine we next tried the action of sodic ethylate when heated on the bromdinitroresorcine diethylether, as it was possible that this substitution could take place only at the moment of the replacement of the other two atoms of bromine by the ethoxy radicals, and in that case boiling sodic ethylate would not convert the ready formed bromdinitroresorcine diethylether into the dinitroresorcine diethylether. Accordingly 3 gr. of bromdinitroresorcine diethylether were mixed with the sodic ethylate from 0.6 gr. of sodium dissolved in alcohol,* and the

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* We found that benzol must not be added in this case, as it seemed to interfere with the progress of the reaction.

mixture heated to gentle boiling for about ten minutes in a flask under a return condenser, when it had taken on a dark red color, and the curious odor observed in making the dinitroresorcine diethylether was very perceptible. The solvent was then allowed to evaporate spontaneously, and the residue washed with water, which removed sodic bromide (as was proved by the addition of argentic nitrate) and a red impurity. It was then purified by crystallization from hot alcohol, until it showed a constant melting point, when we found that this treatment had lowered the melting point from 184°, that of the bromdinitroresorcine diethylether, to 133°, that of the dinitroresorcine diethylether, which substance the product also resembled in appearance and solubility. To remove all doubt about its nature it was dried at 100° and analyzed, with the following results: —

0.1378 gr. of the substance gave on combustion 0.2354 gr. of carbonic dioxide and 0.0616 gr. of water.

	Calculated for $C_6H_2(C_2H_5O)_2(NO_2)_2$.	Found.
Carbon	46.88	46.58
Hydrogen	4.69	4.97

This proves that the substance is the dinitroresorcine diethylether, and that the principal action of the hot sodic ethylate upon the bromdinitroresorcine diethylether was the replacement of its bromine by hydrogen.

After the experiment just described had proved that the bromine in bromdinitroresorcine diethylether could be replaced by hydrogen by means of boiling sodic ethylate, it seemed of interest to determine whether the same change could be brought about by other reagents, and we tried first alcohol alone, which might produce this action by giving aldehyd and hydrobromic acid as secondary products, although this was not at all probable since the bromdinitroresorcine diethylether was purified by crystallization from hot alcohol; and indeed, after boiling it with alcohol for a long time in a flask under a return condenser, the result was entirely negative, nothing but unaltered bromdinitroresorcine diethylether melting at 184° being obtained on evaporation of the alcoholic solution.

From the action of malonic ester on bromdinitroresorcine diethylether we expected better results, because, although it is true that malonic ester has no action on tribromdinitrobenzol (see these Proceedings, xxiv. 308, and the concluding section of this paper), in the formation of bromdinitrophenylmalonic ester it seems to replace one

atom of bromine by hydrogen in the dibromdinitrophenylmalonic ester* (which we must infer is an intermediate product in the reaction), and if this replacement is made possible by the presence of the malonic ester radical $CH(COOC_2H_5)_2$ in the molecule, we thought that perhaps the two ethoxy radicals in bromdinitroresorcine diethylether might produce the same effect. The result of the experiment, however, was again negative, whether carried on cold or hot, as the solid product melted at 184°; and the same result was obtained if acetacetic ester was used instead of malonic ester, although in this latter case the substances were boiled together for four hours.

Supposing from the negative results of these experiments that the presence of sodium malonic ester as well as malonic ester was necessary for the replacement of bromine by hydrogen in the hypothetical dibromdinitrophenylmalonic ester, (leading to an immediate formation of acetylenetetracarbonic ester † as the secondary product,) we tried the action of such a mixture, that is, one molecule of malonic ester to one molecule of sodium malonic ester, upon the bromdinitroresorcine diethylether in alcoholic solution, at first in the cold for five days, that is, under the conditions used in the preparation of bromdinitrophenylmalonic ester, but at the end of this time no sodic bromide could be detected, and essentially all the original ether was recovered unaltered. In another experiment the mixture was heated on the steam bath for fifteen minutes, but, although a distinct red color appeared, the reaction could have been at best a very limited one, as essentially all the bromdinitroresorcine diethylether was recovered unaltered, so that the new substance, if any were formed, was present in such small quantity that we were unable to detect it. It follows from these experiments, that the atom of bromine in bromdinitroresorcine diethylether is more firmly attached to the molecule than the second atom of bromine in the hypothetical dibromdinitrophenylmalonic ester, since this is replaced by hydrogen through the agency of malonic and sodium malonic esters, or more probably by the malonic ester alone considering the formation of tartronic acid. ‡

Action of Sodic Methylate on Tribromdinitrobenzol.

We took up this subject because it was possible that the action of sodic methylate might be different from that of sodic ethylate described in the preceding sections; but we have found that this is not

* These Proceedings, xxiv. 239. † Ibid., 265. ‡ Ibid., 238.

the case, unfortunately at an expense of time and labor entirely out of proportion to the value of the results obtained.

Our experience with sodic ethylate induced us at first to try the action of sodic methylate in the cold; but as we soon found that the same products were obtained when the action was assisted by heat, we have usually proceeded in this way, since, when boiling, the reaction runs to an end in ten minutes, whereas in the cold it takes about two days. Finally we adopted the following method. 10 gr. of tribromdinitrobenzol dissolved in about 20 c. c. of benzol were mixed with a solution in methyl alcohol of the sodic methylate from 1.7 gr. of sodium, and the mixture boiled for ten minutes on the steam bath in a flask fitted with a return condenser, when a clear red solution was obtained, which on cooling deposited white crystals. These were filtered out, the filtrate allowed to evaporate to dryness, and the residue and crystals extracted three or four times with small amounts of hot alcohol, as in this way a viscous impurity was removed, the nature of which will be considered later. The purification of the less soluble portion offered great difficulties, which was the more surprising because it was but slightly soluble in any solvent, so that the separation of it from the viscous product was very easy, and by crystallization from hot alcohol we soon obtained a substance showing the constant melting point 237°–238°; but the results of its analysis did not agree with those calculated for bromdinitroresorcine dimethylether, as is shown by the following comparison:—

	Calculated for $C_6HBr(NO_2)_2(OCH_3)_2$.	Found.
Carbon	31.27	32.78
Hydrogen	2.28	3.21
Nitrogen	9.12	10.64
Bromine	26.05	25.02

As these analyses seemed to indicate that the substance was not pure, we crystallized it again several times, using glacial acetic acid as the solvent; and after a new set of analyses had yielded no better results than those given above, we recrystallized six or seven times, this time from acetone, but with no better agreement of the percentages derived from analysis with those corresponding to the formula. As the substance crystallized very well, we were inclined to think at first that we had a compound different from the bromdinitroresorcine dimethylether, probably with a higher molecular weight. Accordingly, we tried to determine the molecular weight

of the substance by the method of Raoult, and obtained numbers not too far removed from the molecular weight of bromdinitroresorcine dimethylether; but we do not think these results of any value, as the solubility of the substance in glacial acetic acid was so slight that the differences in the depression of the freezing point for different molecular weights fell almost within the limits of error of the process. After many other experiments to determine the nature of this substance, which led to no result, we found at last in the anilido compound derived from it a body which could be purified by crystallization, and from the analysis of which a safe inference could be drawn in regard to the nature of the substance melting at 237°–238°.

Anilidodinitroresorcine Dimethylether,
$C_6H(C_6H_5NH)(CH_3O)_2(NO_2)_2$.

This substance was prepared by heating the body melting at 237°–238° with an excess of aniline to a temperature somewhat above 100° for about twelve hours, when the product was acidified with dilute sulphuric acid, washed carefully with water till all aniline salts were removed, and purified by crystallization from hot alcohol until it showed the constant melting point 196°. During this crystallization we observed indications that we were dealing with a mixture, as the constant melting point 196° was reached only when working with large quantities, and after repeated crystallization; but the impurity which seemed to melt near 206° was present in such small quantity that we were unable to determine its nature. The pure anilido compound was dried at 100°, and analyzed with the following results:—

I. 0.2973 gr. of the substance gave on combustion 0.5733 gr. of carbonic dioxide and 0.1167 gr. of water.

II. 0.2064 gr. of the substance gave 23.7 c.c. of nitrogen at a temperature of 22°.5 and a pressure of 761 mm.

	Calculated for $C_6H(C_6H_5NH)(CH_3O)_2(NO_2)_2$.	Found. I.	Found. II.
Carbon	52.66	52.59	
Hydrogen	4.08	4.36	
Nitrogen	13.16		13.02

From this it appears that the anilido compound is anilidodinitroresorcine dimethylether, and consequently that the substance melting at 237°–238° must be essentially the bromdinitroresorcine dimethylether, but that it contains some impurity, which cannot be removed from it even by very long continued crystallization from alcohol,

glacial acetic acid, or acetone; and this view is confirmed by the behavior of the anilido compound on crystallization described above. Another determination of the nature of the substance melting at 237°–238° will be given below, when we describe its conversion into dinitroresorcine dimethylether. The fact that in the action described above only the bromine was replaced by the aniline radical C_6H_5NH surprised us, as we had expected that the methoxy groups would undergo a similar replacement owing to their position in regard to the nitro groups.

Properties of Anilidodinitroresorcine Dimethylether,
$C_6H(C_6H_5NH)(CH_3O)_2(NO_2)_2$.

This substance forms bright yellow needles, or very slender prisms, which show some tendency to unite in radiating groups. It melts at 196°, and is nearly but not quite insoluble in water; not very soluble in cold ethyl or methyl alcohol, more soluble in hot; freely soluble in chloroform or acetone; soluble in benzol or glacial acetic acid; slightly in ether; very slightly in carbonic disulphide, and insoluble in ligroine. Alcohol is the best solvent for it.

Properties of Bromdinitroresorcine Dimethylether,
$C_6HBr(CH_3O)_2(NO_2)_2$.

Although we did not succeed in getting this substance absolutely pure, we think it worth while to give its properties, as the slight amount of impurity present could have influenced them but little, and they differ rather strikingly from those of the corresponding ethyl compound. When crystallized from glacial acetic acid by cooling, it forms prisms terminated by a single rhombic plane at an acute angle to the sides of the prism, which are so short that the crystal looks almost like a rhombohedron; these crystals are white with a faint yellowish tinge, and often a millimeter long. When crystallized by slow evaporation of the glacial acetic acid solution the crystals are converted into long well formed prisms, and the single rhombic plane which forms the principal termination is usually modified by other smaller planes. The highest melting point which we have obtained for this substance was 237°–238°, but the analyses showed that even when melting at this point it was still far from pure. It is nearly insoluble in water, its solubility being perhaps somewhat increased by boiling; very slightly soluble in ethyl or methyl alcohol, the solubility somewhat increased by heat; slightly soluble in acetone, benzol, chloroform, glacial acetic acid, or nitro-

benzol; very slightly in ether or carbonic disulphide; insoluble in ligroine. The best solvent for it is acetone or glacial acetic acid, as it is more soluble in these liquids than in any other; but its slight solubility in all the common solvents is one of its most striking properties.

Dinitroresorcine Dimethylether, $C_6H_2(CH_3O)_2(NO_2)_2$.

This substance was formed in addition to the bromdinitroresorcine dimethylether by the action of sodic methylate in methyl alcoholic solution upon tribromdinitrobenzol, whether the substances were heated together, or the action was allowed to take place in the cold. The action of sodic methylate, therefore, on account of this indifference to the effect of temperature, is unlike that of sodic ethylate, which gave only bromdinitroresorcine diethylether in the cold, and when heated only dinitroresorcine diethylether. The dinitroresorcine dimethylether, which was formed in comparatively small quantity, was obtained from the alcoholic washings and mother liquors of the substance melting at 237°–238°. The residue left after the evaporation of the alcohol was a viscous mass, which contained in addition to the substance of which we were in search an oily impurity similar to that obtained from the ethyl compound and a little bromdinitroresorcine dimethylether. It was therefore a matter of some difficulty to isolate a pure substance from it, but we finally succeeded by repeated crystallization from hot alcohol, during which crystals of two sorts were obtained, one consisting of white needles turning brown in the air, the other of lemon-yellow rhombic crystals, which appeared especially during the earlier parts of the crystallization, and were gradually converted into the white needles. That the difference between the two forms consisted in the presence of one molecule of alcohol of crystallization in the white needles was shown by the following analytical results: —

I. 0.9817 gr. of the air-dried substance lost 0.0177 gr. at 100°.
II. 0.7617 gr. of the substance dried *in vacuo* lost 0.0142 gr. at 100°.

	Calculated for $C_6H_2(CH_3O)_2(NO_2)_2C_2H_5OH$.	Found. I.	II.
Alcohol	16.79	18.03	18.64

These numbers agree somewhat better with the percentages calculated for three molecules of *water* of crystallization; but, apart from the improbability that the substance would take up water when crystallized from ordinary alcohol, we have found that the liquid given

off, when the needles were heated in a test tube, dissolved the crystals clinging to the side of the tube, and that the substance dried at 100°, when recrystallized from absolute alcohol, gave white prisms like those whose analysis is given above. The analysis which follows was made with the white needles after they had been dried at 100°, and therefore freed from their alcohol of crystallization.

0.2688 gr. of the substance gave on combustion 0.4092 gr. of carbonic dioxide and 0.1027 gr. of water.

	Calculated for $C_6H_2(CH_3O)_2(NO_2)_2$.	Found.
Carbon	42.11	41.52
Hydrogen	3.51	4.25

The substance contains no bromine.

From these results it is evident that the substance is the dinitroresorcine dimethylether, but its melting point, 167°, shows that it is isomeric with the substance * of this composition already known, which melts at 67°.

Properties. — The dinitroresorcine dimethylether was obtained crystallized with one molecule of alcohol, and also in crystals free from alcohol. When containing a molecule of alcohol it forms sheaves or bunches of white needles, or slender prisms often a centimeter long terminated by two planes at a very obtuse angle to each other, or less often a single plane at an acute angle to the sides; frequently also a single plane at right angles to the sides was observed, but we were inclined to consider this due to cleavage rather than a real termination of the crystal. These two prevailing forms, the two planes at an obtuse angle, and the single plane at a right angle, give a general square-ended effect to the crystals which is characteristic. On exposure to the air these crystals turn purplish brown. When containing no alcohol of crystallization, it forms short thick and broad crystals, apparently prisms of the monoclinic system somewhat like certain felspars or rhombic crystals made up by the twinning of such prisms along one diagonal of the rhomb, and having a lemon-yellow color, which is not altered by exposure to the air. The melting point is 167°, but the white needles melt a degree and a half below this point, probably on account of the presence of the vapor of alcohol. The substance is nearly insoluble in cold water, somewhat more soluble in hot; slightly soluble in cold ethyl or methyl alcohol, more soluble in

* Hönig, Ber. d. ch. G., xi. 1041.

hot; very freely soluble in acetone; freely in glacial acetic acid or benzol; soluble in chloroform; slightly soluble in ether, less so in carbonic disulphide; and essentially insoluble in ligroine. The best solvent for it is boiling alcohol. The white needles, if recrystallized from chloroform or glacial acetic acid, give crystals of the lemon-yellow variety (that is free from alcohol). Strong sulphuric acid in the cold has little if any action on it, when hot it dissolves a small quantity forming a yellow solution; strong nitric acid does not dissolve it in the cold, but when hot dissolves it, forming a very pale yellowish solution; strong hydrochloric acid has no action on it, either cold or hot.

The dinitroresorcine dimethylether was also made from the substance melting at 237°–238° (impure bromdinitroresorcine dimethylether) by heating it to boiling with sodic methylate in methyl alcohol solution for one hour in a flask with a return condenser, at the end of which time the formation of dinitroresorcine dimethylether was proved by the melting point, 167°, and the characteristic form of the crystals. This experiment shows that the action with the methyl compounds is similar to that with the ethyl compounds already described, but it takes place less easily, since in the ethyl series heating for ten minutes was sufficient to complete the action, whereas with the methylate boiling for an hour was necessary. This formation of dinitroresorcine dimethylether furnishes us with another and most convincing proof that the substance melting at 237°–238° is essentially bromdinitroresorcine dimethylether, confirming our work with the anilido compound.

Some experiments on the action of sodic isoamylate upon tribromdinitrobenzol gave under the conditions used with the ethylate and methylate only a viscous liquid, which did not solidify even after standing for two months, and as it did not distil with steam we decided that its purification would take more time than our interest in this subject would warrant, and accordingly abandoned this branch of the research.

Action of Sodic Phenolate on Tribromdinitrobenzol.

To study this action, 30 gr. of tribromdinitrobenzol dissolved in a mixture of alcohol and benzol were mixed with an alcoholic solution of 20.8 gr. of phenol previously converted into the sodium salt by the addition of a concentrated aqueous solution of 8.8 gr. of sodic hydrate, and allowed to stand at ordinary temperatures over night. The amount of phenol used corresponds to three molecules for every molecule of the tribromdinitrobenzol. The solution turned light yellow,

and deposited some crystals, apparently tribromdinitrobenzol, but the action was very limited, if any had taken place. Accordingly the mixture was heated on the steam bath in a flask with a return condenser for ten to twelve hours, when it turned dark brown, and after the solvent had been distilled off there was left in the flask a brownish viscous residue of the most uninviting appearance. This was thoroughly washed with water, and then allowed to stand for several days, which rendered it more solid; it was then washed three or four times with small quantities of cold alcohol, which removed much but not by any means all of the oily impurity, and the still viscous residue recrystallized from a mixture of alcohol and benzol until it showed the constant melting point 165°, when it was dried at 100°, and analyzed with the following results: —

I. 0.3128 gr. of the substance gave on combustion 0.5781 gr. of carbonic dioxide and 0.0790 gr. of water.

II. 0.2051 gr. of the substance gave according to the method of Carius 0.0888 gr. of argentic bromide.

	Calculated for $C_6HBr(C_6H_5O)_2(NO_2)_2$.	Found. I.	II.
Carbon	50.12	50.40	
Hydrogen	2.55	2.81	
Bromine	18.57		18.43

These results prove that the substance is the bromdinitroresorcine diphenylether. We may add, that in one preparation in addition to this a substance was obtained crystallizing in square plates and melting at about 158°, but in too small quantity for analysis, and we have not succeeded in making it again. We can say nothing about the nature of the oily product of the reaction, as we could find no way of purifying it.

Properties of Bromdinitroresorcine Diphenylether, $C_6HBr(C_6H_5O)_2(NO_2)_2$.

This substance forms woolly masses of irregularly radiating needles which under the microscope appear long and rather slender, with either a rounded sharpening at the point or else very sharp tapering ends; the substance is white at first, but turns to a pale chocolate-brown on exposure to the air. It melts at 165°, and is very slightly soluble in water whether cold or hot; slightly soluble in cold alcohol, more soluble in hot but not freely; rather more soluble in methyl than in ethyl alcohol, but not freely soluble even in this when hot; very freely soluble in chloroform; freely in benzol or acetone; soluble

in ether; slightly soluble in glacial acetic acid or carbonic disulphide; very slightly soluble in ligroine. The best solvent for it is a mixture of alcohol and benzol. Neither strong sulphuric nor hydrochloric acid seemed to have any action on it, hot or cold; but strong nitric acid dissolved it after a few minutes' heating, and gave on dilution a new substance melting above 200°, probably a nitro compound. Sodic hydrate in solution has no perceptible action on the substance.

The removal of the bromine from the bromdinitroresorcine diphenylether interested us especially, as the somewhat more acid nature of the phenol radical (C_6H_5O) would we thought exercise a marked influence on it; unfortunately, however, the product has proved completely unmanageable, so that we can give only a very imperfect account of this action. We tried first hot sodic ethylate, but found that the substance was much more susceptible to its action than the corresponding ethyl or methyl compounds, showing signs of decomposition by turning dark when the mixture was heated for ten minutes; and although a less colored solution was obtained when we heated for only three or four minutes on the steam bath, the residue left after spontaneous evaporation of the alcohol was a dark-colored oily liquid which showed no signs of solidification, but gradually changed into a black tar after standing some months, and could not be brought into a state fit for analysis by any method we have been able to devise. The aqueous wash water from this substance contained sodic bromide, so that there is no question that the bromine has been removed, but we are unable to determine whether it has been replaced by hydrogen or ethoxyl.

We thought it possible that the bromine might be removed from bromdinitroresorcine diphenylether by phenol, tribromphenol being formed; but after heating the substances together on the steam bath for two days, essentially all the bromdinitroresorcine diphenylether was recovered unaltered. A mixture of sodium malonic ester with an excess of malonic ester seemed to have more effect, as the liquid turned first pale yellow and then red. It was allowed to stand in the cold for several weeks, when it was found that a small amount of sodic bromide had been formed; but the action was a very limited one, as almost all of the bromdinitroresorcine diphenylether was recovered unaltered, and the new compound was present in such small quantity that we did not succeed in isolating it.

Experiments with Tribromtrinitrobenzol.

After we had found that the bromine in bromdinitroresorcine diethylether could be replaced with hydrogen by the action of hot

sodic ethylate, it became interesting to find out whether this was the same atom of bromine which undergoes a similar replacement in making bromdinitrophenylmalonic ester, that is, the atom which stands between the two nitro groups, and the easiest way to do this seemed to be to take up the study of the tribromtrinitrobenzol, in which all the atoms of bromine are similarly placed. This we have done, but without the desired result, as the sodic alcoholates show with tribromtrinitrobenzol actions entirely different from those with the corresponding dinitro compound.

Action of Sodic Ethylate on Tribromtrinitrobenzol.

To study this action 10 gr. of tribromtrinitrobenzol (symmetrical, melting at 285°) were covered with ordinary alcohol in a flask, and to the mixture of crystals and alcohol 1.6 gr. of sodium (three atoms of sodium would be a little over 1.5 gr.) previously converted into sodic ethylate was added, in small portions at a time, the flask being immersed in cold water and shaken after each addition so as to avoid a rise of temperature * in any part of the liquid. The first drop of the alcoholic solution of sodic ethylate turned red on touching the liquid in the flask, and then faded to yellow; but as the remainder of the sodic ethylate was added, the color increased in intensity, until at last it had become a deep blood-red, while at the same time the undissolved solid began to diminish in quantity, and finally entirely disappeared, leaving a clear solution, thus showing that all the tribromtrinitrobenzol had been used up, as it is nearly insoluble in alcohol. The mixture was allowed to stand over night, when it was found that a fresh amount of solid had been deposited, the solvent was then allowed to evaporate spontaneously, the residue (including the solid which had separated over night) washed with water until free from inorganic matter, and purified by crystallization from alcohol until it showed the constant melting point 101°, after which it was dried at about 70° and analyzed, with the following unexpected results: —

I. 0.3519 gr. of the substance gave on combustion 0.3427 gr. of carbonic dioxide and 0.0742 gr. of water.

II. 0.2883 gr. of the substance gave on combustion 0.2795 gr. of carbonic dioxide and 0.0632 gr. of water.

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* If the tribromtrinitrobenzol was dissolved in benzol, the action was so violent that it was almost impossible to avoid a rise of temperature.

III. 0.3165 gr. of the substance gave 9.8 c.c. of nitrogen at a temperature of 25° and a pressure of 764.7 mm.

IV. 0.2315 gr. of the substance gave by the method of Carius 0.2912 gr. of argentic bromide.

V. 0.1588 gr. of the substance gave 0.2002 gr. of argentic bromide.

	Calculated for $C_6Br_3NO_2(C_2H_5O)_2$.	Found. I.	II.	III.	IV.	V.
Carbon	26.79	26.56	26.43			
Hydrogen	2.23	2.34	2.44			
Nitrogen	3.13			3.48		
Bromine	53.57				53.55	53.64

These results show that the action is entirely different from that with tribromdinitrobenzol, for this gave with sodic ethylate bromdinitroresorcine diethylether, $C_6HBr(OC_2H_5)_2(NO_2)_2$, by the replacement of two atoms of bromine by two ethoxy radicals, whereas here under the same conditions we have the tribromnitroresorcine diethylether, which must have been formed by the replacement of two nitro groups by two ethoxy radicals. We have sought the confirmation of our analytical results, which their strangeness certainly requires, in the examination of the sodium salt formed in the reaction, which should be sodic nitrite instead of the sodic bromide which would have been formed if the reaction had run as it did with the dinitro compound. The aqueous washings from a new preparation of the substance melting at 101° gave after acidification with nitric acid only a faint turbidity with argentic nitrate, showing that only a trace of sodic bromide had been formed, whereas from other portions of the wash water we obtained the strongest reactions for a nitrite, as the following statement shows. Potassic iodide and starch paste acidified with dilute sulphuric acid gave a very deep blue color; ferrous sulphate and sulphuric acid, a brownish black color throughout the whole solution; a portion of the residue from evaporation of the wash water added to strong sulphuric acid and phenol gave a reddish brown color quickly passing through green to blue; strong sulphuric acid added to the residue from the evaporation of the wash water gave off a gas recognized as nitrous fumes by the red color and odor. There can be no doubt, therefore, that the sodic ethylate acts on tribromtrinitrobenzol according to the following reaction:—

$$C_6Br_3(NO_2)_3 + 2\,C_2H_5ONa = C_6Br_3NO_2(C_2H_5O)_2 + 2\,NaNO_2.$$

We may add, that, as we felt we could not be too careful in a case of this kind, the second specimen of tribromnitroresorcine diethylether

was made from a quantity of tribromtrinitrobenzol, the purity of which had been proved by analysis in addition to the melting point, found 53.60 per cent of bromine instead of the 53.33 per cent required by the formula.

As potassium compounds behave in many respects differently from the corresponding sodium compounds, we have repeated the experiment with potassic in place of sodic ethylate, but with the same result, that is, tribromnitroresorcine diethylether melting at 101° and potassic nitrite.

Properties of Tribromnitroresorcine Diethylether, $C_6Br_3NO_2(OC_2H_5)_2$. — This substance forms well developed white flat prisms, usually with square ends, but sometimes terminated by two planes at an obtuse angle. It melts at 101°, and is very slightly if at all soluble in water, whether cold or hot; easily soluble in cold ethyl or methyl alcohol, still more freely in hot; very freely soluble in chloroform; freely in benzol; soluble in ether, acetone, carbonic disulphide, or glacial acetic acid; slightly soluble in ligroine. Hot alcohol is the best solvent for it. The three strong acids seem to have no action on it, whether they are hot or cold. Aniline dissolves it, but has no other action on it at ordinary temperatures, or even at 150°; at higher temperatures a substance similar to rosaniline is formed. A mixture of malonic ester and sodium malonic ester was allowed to stand for several weeks with an alcoholic solution of this substance; but, although at the end of this time the liquid had assumed a slight reddish color, and a little sodic bromide (but no nitrite) had been formed, the action was so limited that the only organic compound which could be detected in the product was unaltered tribromnitroresorcine diethylether melting at 101°. It appears from these experiments that the tribromnitroresorcine diethylether is not an especially reactive substance, and yet when it was boiled with an alcoholic solution of sodic ethylate a reaction took place, as was shown by the dark color which the solution assumed, and the formation of a considerable amount of sodic nitrite, proved by the test with potassic iodide, starch, and dilute sulphuric acid. Unfortunately the end of the term prevented us from isolating the organic product, or more probably products, of this reaction, but the work will be continued next year.

Tribromdinitrophenetol, $C_6Br_3(NO_2)_2OC_2H_5$.

In our first experiment on the action of sodic ethylate on tribromtrinitrobenzol the conditions were somewhat different from those described above, which gave us the tribromdinitroresorcine diethyl-

ether, since benzol was used in addition to alcohol as a solvent, and no pains were taken to cool the liquid, although the reaction produced a tolerable amount of heat. The product, which was worked up by spontaneous evaporation of the solvent, washing, and recrystallization from alcohol, showed the constant melting point 147°, instead of 101°. Upon trying to make more of this substance in the same way, we obtained a product which was evidently a mixture of the substance melting at 101° and that melting at 147°, but the end of the term has prevented us from making out the exact conditions necessary for the production of the substance melting at 147° as the principal product. Fortunately the amount of this substance made in our first experiment was sufficient for its characterization. It was dried at 100°, and analyzed with the following results: —

I. 0.1607 gr. of the substance gave on combustion 0.1237 gr. of carbonic dioxide and 0.0263 gr. of water.

II. 0.2142 gr. of the substance gave by the method of Carius 0.2683 gr. of argentic bromide.

III. 0.1736 gr. of the substance gave 0.2192 gr. of argentic bromide.

	Calculated for $C_6Br_3(NO_2)_2OC_2H_5$.	Found. I	II.	III.
Carbon	21.38	20.99		
Hydrogen	1.11	1.82		
Bromine	53.46		53.31	53.74

Properties. — The tribromdinitrophenetol occurs in white, well formed, slender, nearly square prisms often a centimeter long, terminated by a single plane at an acute angle to the sides. It melts at 147°, and is soluble in cold ethyl or methyl alcohol, more freely in hot; freely soluble in benzol, chloroform, glacial acetic acid, or acetone; soluble in ether or carbonic disulphide; almost insoluble in ligroine. The best solvent for it is hot alcohol. None of the strong acids seem to have any action on it.

Action of Sodic Methylate on Tribromtrinitrobenzol.

Since sodic ethylate had acted so abnormally with tribromtrinitrobenzol, it seemed of interest to study the action of sodic methylate on this compound and accordingly we proceeded as follows.

10 gr. of tribromtrinitrobenzol in a flask were covered with absolute methyl alcohol, and the solution of sodic methylate made from 1.5 gr. of sodium was added, observing the precautions for keeping the mixture cool described under the preparation of the corresponding

ethyl compound. The first drop of sodic methylate solution turned red on touching the liquid in the flask, but this color faded to yellow as it was diffused through the solution; with continued addition of the methylate the color increased in intensity, becoming finally blood red. It seemed as if the action of the sodic methylate was more vigorous than that of the ethylate, as after about three quarters of an hour the whole of the tribromtrinitrobenzol had disappeared, leaving a clear red solution, but nevertheless the mixture was allowed to stand over night to make certain that the reaction had come to an end, after which the solvent was evaporated spontaneously, the residue washed with water (which gave a test for sodic nitrite) and crystallized from hot alcohol until it showed the constant melting point 126°, when it was dried at about 70°, and analyzed with the following results: —

I. 0.2856 gr. of the substance gave 10.1 c.c. of nitrogen at a temperature of 25° and a pressure of 755.5 mm.

II. 0.2295 gr. of the substance gave by the method of Carius 0.3072 gr. of argentic bromide.

III. 0.2311 gr. of the substance gave 0.3096 gr. of argentic bromide.

	Calculated for $C_6Br_3NO_2(CH_3O)_2$.	Found. I.	II.	III
Nitrogen	3.33	3.92		
Bromine	57.15		56.97	57.03

Properties of Tribromnitroresorcine Dimethylether, $C_6Br_3NO_2(CH_3O)_2$. — This substance crystallizes in white flattened prisms terminated usually by a single plane at a very sharp angle to the sides, rarely by two planes at an obtuse angle to each other, or also rarely the ends are square. It melts at 126°, and is nearly insoluble in cold water, perhaps a little more soluble in hot; only moderately soluble in ethyl alcohol even when hot, less soluble in it cold. It is much less soluble in alcohol than the corresponding ethyl compound; in this these two compounds resemble the methyl and ethyl compounds of the bromdinitroresorcine. Slightly soluble in cold methyl alcohol, more soluble in hot; freely soluble in benzol, chloroform, or acetone; soluble in ether, carbonic disulphide, or glacial acetic acid; very slightly soluble in ligroine. The three strong acids have no apparent action on it.

Action of Sodic Phenolate on Tribromtrinitrobenzol.

After several unsuccessful experiments we obtained satisfactory results as follows. 10 gr. of tribromtrinitrobenzol were dissolved in a mixture of benzol and ordinary alcohol, and mixed with the sodic

phenolate made from somewhat more than 6.1 gr. of phenol treated with the sodic ethylate from 1.3 gr. of sodium. The slight excess of phenol was used to avoid the presence of sodic ethylate, and the salt was added in suspension in alcohol. The mixture was then heated on the steam bath under a return condenser for less than five minutes, when it had turned bright green, but was perfectly clear, and upon cooling solidified, since it became filled with loose woolly masses of radiating needles looking like thistle balls; this sudden solidification of the solution as it cools is very striking. The crystals with the residue from the mother liquors were washed with water (which took up much sodic bromide), and crystallized from a mixture of alcohol and benzol until they showed the constant melting point 175°, when they were dried at 100° and analyzed. If benzol was not used in preparing this substance, the action was only incomplete even after boiling for half an hour. The formation of sodic bromide instead of sodic nitrite, and the green instead of red color, showed that this action had gone differently from that with sodic ethylate or methylate, and this was confirmed by the following analyses: —

I. 0.2689 gr. of the substance gave on combustion 0.5823 gr. of carbonic dioxide and 0.0850 gr. of water.

II. 0.2439 gr. of the substance gave 0.5306 gr. of carbonic dioxide and 0.0775 gr. of water.

III. 0.2448 gr. of the substance gave 18.6 c.c. of nitrogen at a temperature of 23° and a pressure of 758.1 mm.

	Calculated for $C_6(C_6H_5O)_3(NO_2)_3$.	Found. I.	II.	III.
Carbon	58.89	59.05	59.33	
Hydrogen	3.07	3.51	3.53	
Nitrogen	8.59			8.55

The substance was free from bromine. This action therefore has gone entirely differently from any of the others studied in this paper, consisting in the simple replacement of each bromine by one phenoxy radical (C_6H_5O), and the substance is the trinitrophloroglucine triphenylether.

Properties of the Trinitrophloroglucine Triphenylether, $C_6(NO_2)_3(C_6H_5O)_3$.

This substance crystallizes in long very slender white needles, matted together into globular woolly masses, which turn olive-brown on exposure to the air. It melts at 175°, and is essentially insoluble

in water, whether cold or hot; slightly soluble in cold alcohol, more soluble in hot, but not freely; its solubility in methyl alcohol is similar to that in ethyl alcohol; very freely soluble in acetone or chloroform; freely soluble in benzol or glacial acetic acid; slightly soluble in ether or carbonic disulphide; very slightly soluble in ligroine. The three strong acids have no apparent action on it, whether hot or cold.

This is the only case in which we have observed the replacement of all three of the atoms of bromine by the radical of an alcoholate, and it is to be noted that the phenoxy radical introduced here is the most acid one which we have succeeded in introducing, whereas in the other cases where all the bromine has been replaced by the same radical this has been the alkaline amido or anilido group, —

$C_6(NH_2)_3(NO_2)_3$, * $C_6(NHC_6H_5)_3(NO_2)_3$, † $C_6H(NH_2)_3(NO_2)_2$, ‡ $C_6H(NHC_6H_5)_3(NO_2)_2$. §

Experiments with Sodic Acetate, Sodic Picrate, or Sodic Nitromethane on Tribromdinitrobenzol or Tribromtrinitrobenzol.

In order to study the action of more acid radicals upon tribromdinitrobenzol we mixed 5 gr. of it with 3 gr. of sodic acetate dissolved in dilute alcohol, and, as there seemed to be no action in the cold, heated the mixture in a flask with a return condenser on the steam bath for eight hours, at the end of which time the tribromdinitrobenzol was recovered unaltered as indicated by its melting point, 192°. A similar mixture was next heated to 100° for two days in a soda-water bottle closed with an india-rubber stopper, at the end of which time 4.9 gr. of tribromdinitrobenzol melting at 192° were recovered. It is evident from these experiments that sodic acetate has no action on tribromdinitrobenzol at 100°.

As we hoped that the slighter acidity of picric acid might allow it to react on tribromdinitrobenzol, although sodic acetate would not, we next allowed 6.3 gr. of tribromdinitrobenzol to stand for a week with 12 gr. of sodic picrate suspended in alcohol, and, as at the end of this time no sodic bromide had been formed, we heated it in a flask with a return condenser on the steam bath for two days, but even after this no sodic bromide could be detected, and 6.2 gr. of tribromdinitrobenzol melting at 192° were recovered in place of the 6.3 gr.

* These Proceedings, xxiii. 142.
† Ibid., 145.
‡ Ibid., xxiv. 106.
§ Ibid., 111.

used. Sodic picrate, therefore, does not act on tribromdinitrobenzol at 100°.

In the hope that tribromtrinitrobenzol would prove more reactive than the dinitro compound in this case, as it has in many others, the experiment was repeated with this substance, 5 gr. of tribromtrinitrobenzol to 8.3 gr. of sodic picrate mixed with alcohol and benzol being used, but after twelve hours' boiling the 5 gr. of the trinitro compound were recovered unaltered.

The sodium salt of nitromethane was also tried with tribromdinitrobenzol. 10 gr. of the latter substance dissolved in alcohol and benzol were mixed with 4.5 gr. of nitromethane previously treated with the sodic ethylate from 1.8 gr. of sodium. The mixture after standing for some time in the cold became brownish red, and the sodium salt suspended in the solution gradually disappeared, but upon working up the product 9.5 gr. of the tribromdinitrobenzol were recovered unaltered, showing that there had been no action worth considering. In a previous experiment another compound was obtained in small quantity, but we are inclined to ascribe its formation to sodic ethylate, or the products of the decomposition of the sodium salt of nitromethane rather than to that substance itself. We hope to return to this subject next year.

We had intended to include in this research the action of sodic hydrate in alcoholic solution upon tribromdinitrobenzol; but since we obtained from a preliminary experiment bromdinitroresorcine diethylether, recognized by its melting point (182° instead of 184° after one crystallization) as the principal product, we thought the subject did not promise to be of sufficient interest to repay future work.

Some preliminary experiments with mononitrotribrombenzol and sodic ethylate seemed to promise interesting results, but this part of the work must be postponed until next year.

Action of Malonic Ester on Tribromdinitrobenzol.

In previous papers * of this series it has been proved that in the formation of bromdinitrophenylmalonic ester from sodium malonic ester and tribromdinitrobenzol the bromine atom replaced by hydrogen stands between two nitro groups. In view of this fact, it seemed desirable to determine whether the ease with which this atom

* These Proceedings, xxiv. 248, 250 (1889).

of bromine was removed by the action of malonic ester depended only on this position, and experiments were tried and described in a previous paper * which seemed to disprove this view. On returning to the subject, this point seemed to us of so much importance that we determined to repeat the experiment, especially as the conditions under which the malonic ester acted on the tribromdinitrobenzol in the earlier work were not exactly the same as those of the action of the sodium malonic ester in the preparation of bromdinitrophenylmalonic ester; accordingly, in repeating the experiment as described below we have reproduced these conditions as exactly as possible, except that malonic ester was used in place of sodium malonic ester.

To 4 gr. of malonic ester dissolved in 30 c.c. of absolute alcohol were added 5 gr. of tribromdinitrobenzol dissolved in anhydrous benzol, and the mixture was allowed to stand in the cold for three or four days, at the end of which time, there being no signs that a reaction had taken place, the solvent was allowed to evaporate spontaneously, and the malonic ester mother liquor poured off from the crystals, which after careful drying on a steam radiator at about 70° weighed 3.4 gr. and melted at 192° (the melting point of tribromdinitrobenzol). The mother liquor was allowed to stand in a loosely covered dish for a month, when the malonic ester had evaporated, leaving an additional crop of crystals, which after drying as before weighed 1.75 gr., and also showed the melting point of the tribromdinitrobenzol. So that the weight of the recovered tribromdinitrobenzol was 5.15 gr. † This experiment therefore confirms those previously tried,* and proves conclusively that malonic ester has no action upon tribromdinitrobenzol ($BrNO_2BrNO_2BrH$), and consequently that the replacement of the bromine atom by hydrogen in the formation of bromdinitrophenylmalonic ester depends on other conditions in addition to the influence of the nitro groups and other bromine atoms upon it. The discussion of these other conditions will be postponed until we have collected more experimental material.

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* These Proceedings, xxiv. 308 (1889).

† The slight excess (0.15 gr.) over the amount used is easily accounted for by the dust which during the long standing found its way into the loosely covered evaporating dish.

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XI.

MOTION OF ATOMS IN ELECTRICAL DISCHARGES.

By John Trowbridge.

Presented October 8, 1890.

The application of Spectrum Analysis to the measurement of the approach or recession of a star in a direction directly away or directly toward an observer's eye is generally regarded as one of the greatest achievements of modern science. Experiments upon the oscillatory discharge of electricity led me to reflect whether the method which has been used in star observation might not be employed to test the question whether the atoms of the metals of the terminals between which the oscillatory discharge passes are conveyed to and fro by the oscillatory discharge, or whether they are shaken, so to speak, by the discharge, so that they emit to the ether the ripples which appeal to our senses as light and heat. No mention is made here of a convection effect which would take place too slowly to give a spectroscopic effect.

After I had made the experiments which I will shortly describe, and while I was in doubt whether to publish my results, a paper by Prof. J. J. Thomson, Director of the Cavendish Laboratory, Cambridge, England, appeared in the August number of the Philosophical Magazine (1890), "On the Velocity of the Transmission of Electric Disturbances," which contains the following passage: "The very rapid rate with which the electric discharge is propagated through a rare gas compels us to admit that the electricity is not carried by charged atoms moving with this velocity. For if it were, then if the discharge were to take place in air at atmospheric pressure between two parallel plates one centimeter apart, charged to a potential difference of approximately 30,000 volts, the kinetic energy which would have to be communicated to the atoms to make them move with this velocity would be greater than the original potential energy of the

charged plates, assuming that the charge on each atom is that deduced from electrolytic considerations."

The unusual dispersion afforded by a Rowland concave grating led me to test this hypothesis, in so far as it relates to the question, Are the molecules of metals carried with the oscillations of electricity between terminals between which the oscillations take place? A circuit of wire giving a suitable value of self-induction was arranged in connection with a series of Leyden jars. The time of oscillation was calculated from the well known formula, $t = 2\pi\sqrt{LC}$; in which L is the value of the self-induction of the circuit; C, the capacity of the Leyden jars. Preliminary examination of the electric spark taken through this circuit with a revolving mirror showed that the discharge was an oscillatory one. Two different values of self-induction were employed. One gave the duration of a double oscillation $t = .0000003$ of a second; the other gave $t = .0000024$ of a second.

If we denote by V the velocity of light, λ and λ_1 wave lengths, δ the speed of approach of the atom, we shall have $\lambda_1 = \lambda\left(\frac{V}{V+\delta}\right)$.

The distance across which the oscillations took place was six millimeters. Calculation shows that if the iron atoms were conveyed to and fro between the terminals, a broadening of the iron lines in the spectrum would result, which could be readily detected. The broadening might amount to a space equivalent to a whole tenth meter.

The oscillatory spark passed between two iron terminals. One of these terminals was hollow. The hollow terminal was placed in a line perpendicular to the slit of the spectroscope, so that the oscillation of the spark should be toward and away from the slit. If, therefore, the iron atoms moved to and fro with the oscillations of electricity across the air gap, a displacement of the iron lines in the spectrum of the metal would result. There would be both a displacement toward the less refrangible, caused by the recession of the atom, and one toward the most refrangible end of the spectrum, caused by the approach of the atom. The great amount of dispersion afforded by a concave grating of 20,000 lines to the inch enabled me easily to detect a movement of $\frac{1}{100}$ of a wave length. I accordingly took a photograph of the iron lines with the terminals in the position I have described, and on the same plate, immediately above this photograph, a comparison photograph was taken with the terminals parallel to the slit. In this case the iron atoms did not make their supposed ex-

cursions away and toward the slit, and therefore no displacement of the spectrum lines was to be expected.

The photographic plate was exposed in the neighborhood of the great H lines. A movable shutter enabled me to expose different portions of the same plate without changing any adjustments of the apparatus. The resulting photographs showed no displacement of the iron lines. The iron lines in the two photographs met exactly, continued in an unbroken line across the double photograph, and were of the same breadth throughout their extent.

The conclusion seems to be a strong one, that the electrical oscillations do not carry the atoms of metals with them in spark discharges. The atom is merely shaken up, and caused to emit the vibrations or subsidiary ripples which appeal to our senses as light and heat, while the electrical waves pass on without conveying the atoms.

JEFFERSON PHYSICAL LABORATORY.

XII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

THE ANALYSIS OF CUPRIC BROMIDE, AND THE ATOMIC WEIGHT OF COPPER.

By Theodore William Richards.

Presented by the Corresponding Secretary, October 8, 1890.

Introduction.

The uncertainty of knowledge regarding the atomic weight of copper, owing to the widely different values assigned by various experimenters, led nearly four years ago to the beginning of an investigation, of which this paper is the third publication. The two earlier papers * described a number of determinations made by a method which had not until then been successfully applied, — the precipitation of metallic silver from neutral silver solutions by means of metallic copper. The results obtained were in themselves very satisfactory, but differed entirely from the value which has hitherto been accepted with little question by chemists; and the desire to discover, if possible, the cause of this discrepancy, has finally led to the continuance of the investigation.

It is well known that we can rarely find with regard to any element more than one or two compounds which answer the exacting requirements of atomic weight determination; although others of its definite compounds may by their analysis more or less strongly support the verdict of the more exact results. Disagreement implies constant error in one or other of the disagreeing values, and the detection and correction of this constant error can alone give certainty to our conclusions. Much, however, may be learnt by careful study from a new standpoint, and the first step in the present investigation was to discover if possible such an opening.

The basic tendency of cupric salts, and the ready oxidation of cuprous compounds, complicate to such an extent the relations of copper, that the preparation of any one of its salts in a dry state

* These Proceedings, xxii. 342, and xxiii. 177; also Fresenius's Zeitschrift, xxviii. 392.

of perfect purity may be regarded as almost an impossibility. One by one the usual cupric and cuprous compounds were rejected as unsuitable for the foundation of a new research, until finally, after much study, cupric bromide was selected on account of the simplicity and exactness of its analysis, and moreover because by establishing beyond doubt the relation of copper to bromine we connect its atomic weight with precise values previously determined in this laboratory.

The balance used throughout the research was the one used by Professor Cooke in his admirable work upon the atomic weight of antimony, and was kindly loaned by him for the present purpose. A long-armed balance of the best type, manufactured by Becker of New York, it was very perceptibly turned by one twentieth of a milligram with a load of fifty grams in each pan, and showed unusual constancy in its indications. It was kept in a large quiet room of nearly constant temperature, and was protected from unequal heating and from air currents by suitable curtains. The weights were made by Sartorius in Göttingen, the larger ones being of gold-plated brass, and the fractions of a gram of platinum. Three days were spent in their comparison, according to a method somewhat similar to that described by Crookes,* and the very small corrections thus found were tabulated and applied to all results.

Before weighing, every object was allowed to remain in a desiccator near the balance, for at least seven hours. Every weight was determined at least thrice, each time according to a different method of swinging, and all precautions for accuracy were taken which are usual in such work. In the first experiments the weighings were made by substitution, but the conditions were so uniformly constant and the balance so manifestly reliable that this procedure seemed a useless expenditure of time. In fact, the probable error of the ordinary method of weighing under such circumstances is very much less than other possible errors of an investigation like the present. It is certain that the total inaccuracy of any weighing, due to all possible causes combined, could not have exceeded seven or eight one-hundredths of a milligram, and was without doubt usually very much less than that quantity. All weighings were of course reduced to a vacuum standard, allowing for the air displaced by the weights. Since these were standardized with reference to a brass ten-gram piece, it is evident that the fractions of a gram must be calculated as brass, and not as platinum.

* Fresenius's Zeitschrift, vi. 431.

I. Preliminary Work.

Preparation and Analysis of Hydrobromic Acid.

The next step taken was the preparation of hydrobromic acid pure enough to serve as the basis of research. The acid was made from pure potassic bromide and sulphuric acid, according to the method recommended by Dr. Squibb.* It was then purified by repeated fractional distillation, at first in a large platinum retort, and afterward in one of glass; it having been ascertained that the gold used as a solder in the former apparatus was attacked during the process. It was subsequently found that the action of the acid even upon glass was not imperceptible, but as the same retort was used in all later distillations, and as the glass was of good quality, this unavoidable cause of impurity was reduced to a minimum.

The acid was distilled in all ten times, — seven times over potassic bromide, twice over silver bromide, and once alone, — each time the first and last portions of the distillate being rejected. A specimen of the wholly colorless product was preserved for over a year without perceptible change.

The necessity of testing the purity of this hydrobromic acid led at once to the next step of the investigation, the preparation of chemically pure silver. Fused argentic nitrate was first made from pure silver which had been reduced from the chloride by milk sugar and potash. This salt was then dissolved in a large amount of water, and again decomposed by the gradual addition of very dilute hydrochloric acid in slight excess, the precipitate being thoroughly agitated and washed by decantation with dilute hydrochloric acid and hot and cold water. After drying and pulverizing, the pure argentic chloride was digested for six hours with aqua regia, and then again washed with the purest hot and cold water until the filtrate gave no test for chlorine.

The final reduction of the cream-colored product was accomplished as before, by warming it with a dilute solution of the purest caustic potash and milk sugar, which had previously been filtered through a Gooch crucible. Careful testing showed the completion of the reaction, and the resulting pure silver, having been thoroughly washed with dilute sulphuric acid and a very large amount of pure hot water until perfectly clean, was collected and dried upon a quantitative filter. Small portions of the powder were successively supported upon a

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* These Proceedings, xvii. 30.

carbon dish similar to that described by Professor Cooke,* and, after being fused by means of a blowpipe directed downwards, the silver was allowed to cool in a reducing flame. The buttons were hammered upon a clean anvil, scrubbed with sand, rolled out between two plates of pure silver, cut with a hard steel chisel, boiled successively with hydrochloric acid and ammonia, scrubbed once more with sand, and, after heating with melted potassic hydrate in a silver crucible, finally scrubbed, washed, and dried.

In order to prove the absence of any absorbed gases in the resulting metal the following experiments were made.

I. 1.3412 grams of silver heated in vacuo to a low red heat weighed after cooling 1.3412 grams.

II. 1.5763 grams after being subjected to the same treatment weighed 1.5763 grams.

The absolute constancy of these weights is sufficient proof of the point in question. The silver yielded a perfectly clear solution upon treatment with nitric acid and subsequent addition of water, and gave every evidence of being chemically pure.

In order to determine the purity of the hydrobromic acid previously made, the solution of a known weight of the pure silver described above was decomposed by a slight excess of this liquid, and the resulting precipitate was weighed. The metal was dissolved in a very slight excess of warm pure nitric acid diluted with two volumes of water, the whole being contained in the half-litre Erlenmeyer flask which was afterward to serve for the precipitation. The very small amount of gas formed by the decomposition of the nitric acid was forced to pass through a zigzag tube provided with bulbs, in order that the infinitesimal amount of spray might be retained. The tube apparatus was not ground into the flask, but fitted only with moderate tightness, the joint being sealed by water held in place by capillary attraction. After the complete solution of the silver, the contents of the flask were gently boiled to drive off the lower oxides of nitrogen, and the whole was diluted to about two hundred cubic centimeters. To this hot liquid was added very gradually the least possible excess of a dilute solution of known strength made from the hydrobromic acid above described, and the mixture was constantly and violently shaken, the flask being closed with a smooth rubber stopper. After settling, the precipitate was thoroughly washed with hot water, and collected in a

* These Proceedings, xvii. 17.

Gooch perforated crucible with all possible care. The crucible with its contents was dried at 130° to constant weight, and showed no loss in any case on additional heating to 180°.

SYNTHESES OF ARGENTIC BROMIDE.

No. of Experiment.	Silver taken (reduced to Vacuum).	AgBr formed (reduced to Vacuum).	Percentage Ag in AgBr.
	grams.	grams.	
1	1.11235	1.93630	57.447
2	1.57620	2.74335	57.455
3	2.16670	3.77170	57.446
		Average. . . .	57.449
		According to Stas . . .	57.445

The above variation is not greater than a possible error in the operations concerned, and the testimony which these results give to the purity of the materials is sufficient for the present purpose. Other experimenters in this Laboratory have obtained values ranging from 57.442 to 57.450.

Preparation of Cupric Bromide.

The salt used in the preliminary series of experiments upon the atomic weight of copper was formed by the solution of the purest obtainable cupric oxide in the hydrobromic acid which has been described above. For the preparation of the oxide of copper pure electrolytic metal (of the quality used in the experiments published three years ago) was converted into sulphate by means of pure nitric and sulphuric acids, and the resulting salt was purified by six fractional recrystallizations after the expulsion of the remaining nitric acid by heat. From a dilute solution of the purest cupric sulphate acidified with nitric and sulphuric acids, about half the metal was deposited upon the interior of a large platinum dish. The remaining liquid being decanted, the film was washed, redissolved, and partially redeposited through the agency of two Bunsen cells. It was hoped that this fractionation would rid the copper of that probable impurity which almost invariably manifests itself as minute dark spots upon the surface of the film of a completed electrolysis, but the hope proved to be a vain one, and no method of purification was devised which

would wholly remove the difficulty. Some of the copper films obtained in the course of the work were almost free from the minute spots, while others of the same series showed a larger number of them; but the phenomenon did not appear to affect the results. From this it would seem that the supposed impurity might have consisted merely of finely divided copper, but even on the worst supposition the amount was so infinitesimal that it could have had no influence upon the observed atomic weight.

The brilliant metallic film thus prepared was carefully separated from the platinum and thoroughly washed with hot water. The separation of the copper from the dish is greatly facilitated by previously rubbing the surface of this electrode with an exceedingly small quantity of pure semi-liquid paraffin, which seems to fill the microscopic cavities of the platinum without interfering with the continuity of the copper film. The pure washed copper was returned to the clean dish, dissolved in very pure nitric acid, and the product slowly converted into basic nitrate, and finally into oxide, by gradually increasing heat. The last part of the operation was conducted at a low red heat in porcelain, and of the product only the central portions were used in the work. The resulting cupric oxide was a fine black powder, which dissolved completely in acids, and gave every evidence of being chemically pure.

A large quantity of this copper oxide was dissolved in a slight excess of pure hydrobromic acid, and the solution evaporated to dryness over a steam bath. Of course, every possible precaution against dust and other impurity was taken with regard to this as well as to every other operation of the research, neither hydrochloric acid nor ammonia being used in the room devoted to it. During the process of evaporation a very faint odor of bromine was perceptible; and upon the subsequent solution of the brilliant black scales of cupric bromide in water, the clear blue liquid slowly deposited a few microscopic crystals of the basic bromide, which will be described in another place. After standing a few days the crystals ceased to be deposited, and the filtered clear odorless solution remained for about four weeks without further change, serving as the basis of a number of experiments, and furnishing material for the first series of preliminary analyses.

Since it was evidently impossible to obtain the normal salt by the evaporation of the solution at 100° in the air, many attempts were made to prepare it by concentration of the neutral solution over sulphuric acid in air and in nitrogen gas of low tension. The first trials all ended in failure, and it was not until much later that the problem

was successfully solved. The purest salt obtained at this stage of the work consisted of brilliant black crystalline scales, which, contrary to all expectation and all literature * upon the subject, were not very deliquescent unless moistened with strong hydrobromic acid. Since the normal compound invariably seems to lose a trace of bromine on exposure to the air, the lack of deliquescence may be due to a very thin superficial covering of the basic bromide. The normal salt is soluble in a very small amount of water, forming a brownish black solution; this becomes deep purple after the addition of hydrobromic acid, and upon gradual dilution goes through successive shades of brown and dirty green to a most beautiful "robin's egg" blue.

The basic salt above alluded to was found to be quite insoluble in water, hence it seemed probable that the dilute solution of cupric bromide from which it had separated was perfectly normal, and it became an important problem to settle this point. As the normal salts of copper are wholly without action upon a solution of methyl orange, this indicator formed the most convenient test for the neutrality of the liquid in question. To about fifty cubic centimeters of the clear solution of pure cupric bromide, which had remained standing for three weeks, were added two drops of a dilute solution (1 : 400) of methyl orange, and the greenish liquid was thoroughly shaken. Upon equally dividing the solution between two test-tubes, the most careful observation showed no difference in the color of the separate portions. To one tube was then added 0.05 c.c. of a twentieth normal solution of hydrobromic acid (= 0.2 milligram of bromine) and a change from green to gray was perfectly evident when the portions were again compared. A second equal addition of acid produced a purplish hue. The gray was of course due to the simultaneous presence of the red color of the acidified methyl orange, the yellow of the unchanged compound, and the blue of the copper bromide, and proved that some of the indicator had been acted upon by the acid: hence the solution could not have been basic in the first place. In a few words, the solution, containing about one and a half grams of cupric bromide, could not possibly have lacked more than 0.0002 gram of its normal weight of bromine. This being the case, a determination of the relative weights of copper and bromine in such a solution would form a sufficiently accurate basis for the calculation of the atomic weight of copper.

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* Berthemot, Ann. de Chim. et de Physique, 2d Series, xliv. 386 (1830); Löwig, Liebig's Handwört. Ch., iv. 713; Rammelsberg, Pogg. Ann., lv. 246; and many others.

Method of Analysis.

The bromine and copper were determined in separate weighed portions of the solution, according to usual methods. For the estimation of the former, the diluted cupric bromide was slowly added to a slight excess of pure argentic nitrate dissolved in one hundred and fifty cubic centimeters of hot water. In some of the determinations nitric acid was added to the silver nitrate before the precipitation, and in the other cases the acid was added afterward; but the difference in procedure produced no difference in result. The silver bromide settled readily, and was treated in the manner already described.*

The copper was determined in another weighed portion of the solution by electrolysis, after the complete expulsion of the bromine by means of nitric and sulphuric acids. One and a half to three grams of cupric bromide were used in each determination, and usually one part of nitric acid and two parts of sulphuric acid were taken to decompose one part by weight of the salt; but here again the relative quantities were varied without any perceptible effect upon the result. When the bromine and nitric acid had been expelled over the water bath, the residual copper sulphate and sulphuric acid were dissolved in a small quantity of water, and the whole transferred to the platinum crucible which was to serve as the negative electrode. It was found that within reasonable limits the size of the crucible and the dilution of its contents had no important effect upon the deposition of the copper, provided that the strength of the current was properly regulated. With six gravity cells and eighty ohms external resistance it was possible to deposit perfectly half a gram of copper in a coherent film from twenty-five cubic centimeters of solution. The positive electrode consisted in every case of a strong platinum wire fused into the centre of the watch-glass serving as a cover to the crucible. Twice before the completion of each electrolysis the liquid adhering to the lower surface of this lid was washed into the crucible, and the current was always maintained for at least thirty-six hours. Upon breaking the circuit, the sulphuric acid was at once wholly displaced by a stream of distilled water, and after washing by decantation with pure water, alcohol, and ether, the film was finally dried at 95° C. to perfectly constant weight. All the washings were collected in a large porcelain dish, carefully examined in order to be sure that no copper had been carried away, and after evaporation to small bulk

* Page 198 of this paper.

tested with uniformly negative result for the presence of traces of metal in solution. It is almost needless to state, that, in every operation involving the quantitative transference of liquid, the original containing vessel was washed out with the most scrupulous care, and finally tested to prove the absence of any trace of its former contents.

Below is the series of four results obtained from the first cupric bromide solution. About two weeks elapsed between the first and last determinations of this series.

Preliminary Results: First Series.

Determination of Copper.

No. of Experiment.	$CuBr_2$ Solution taken.	Copper found (reduced to vacuum).	Copper in 25 grams Solution (to vac.).
	grams.	grams.	grams.
1	26.400	0.4397	0.4164
2	26.423	0.4401	0.4164
3	52.824	0.8799	0.4164
4	26.454	0.44075	0.4165
		Average . . .	0.41642

Determination of Bromine.

No. of Experiment.	$CuBr_2$ Solution taken.	AgBr found (reduced to vacuum).	Bromine in 25 grams Solution (to vac.).
	grams.	grams.	grams.
5	26.419	2.5995	1.0468
6	26.436	2.6018	1.0471
7	26.413	2.5996	1.0471
8	26.414	2.5990	1.0468
		Average . . .	1.04695

Atomic Weight of Copper.

From above results, if Ag : Br = 108.00 : 80.007, Cu = 63.644.
From results of previous paper, if Ag : Br = 108.00 : 80.007, Cu = 63.640.
According to Hampe, on same basis, Cu = 63.37±.

Since atomic weights are in any case relative, the ratio * Ag : Br = 108.00 : 80.007 will be assumed as the present standard of reference, for the sake of convenience and comparison with previous work. Later, all values will be translated into the various generally accepted standards.

The second series of analyses was made from the more dilute solution of a new sample of the salt, prepared in the same manner as the first, but perhaps somewhat less pure. The object was to seek further evidence of the constancy of the composition of dissolved cupric bromide, and it will be seen that the result agrees moderately well with the former one.

PRELIMINARY RESULTS: SECOND SERIES.

Determination of Copper.

No. of Experiment.	$CuBr_2$ Solution taken.	Copper found (reduced to vacuum).	Copper in 25 grams Solution (to vac.).
	grams.	grams.	grams.
9	77.875	0.8158	0.26190
10	51.891	0.5435	0.26185
		Average . . .	0.26187

Determination of Bromine.

No. of Experiment.	$CuBr_2$ Solution taken.	Silver Bromide found (reduced to vacuum).	Bromine in 25 grams Solution (to vac.).
	grams.	grams.	grams.
11	51.871	3.2114	0.65866
12	51.870	3.2113	0.65865
13	40.308	2.4957	0.65871
		Average . . .	0.65867

Atomic Weight of Copper 63.618

* Although this ratio is not materially different from 108 : 80, we select it as the mean value of all the most accurate determinations.

It is certain that the hydrobromic acid used in making this preparation, notwithstanding the care taken in its manufacture, contained a trace of alkali from the glass retort used in distilling; and the presence of this impurity would tend to lower the observed atomic weight of copper. In order to correct this evil, and also in the hope that free hydrobromic acid might prevent the very slight formation of basic salt which invariably took place on the evaporation of water from the neutral salt, the attempt was made to crystallize the cupric bromide from acid solutions. The crystals were still basic, owing to the surface decomposition of exposed scales, but nevertheless two small distinct preparations of such crystals were dissolved, allowed to deposit their basic salt, and each analyzed for copper and bromine. Neither of these analyses was wholly satisfactory, but for the sake of completeness their final results are given below.

PRELIMINARY RESULTS: THIRD SERIES.

Solution of Crystals.

No. of Experiment.	Weight of Copper (reduced to vacuum).	Weight of AgBr (reduced to vacuum).	Atomic Weight Copper. AgBr = 188.007.
	grams.	grams.	
14 and 15	0.2500	1.4771	63.64
16 and 17	0.5473	3.2348	63.62

All the results thus far given were regarded merely as preliminary ones; and a complete series in which all possible care should be taken, both in preparation and analysis, remained still to be made. But before proceeding to the final determinations it was thought well to make several experiments with the object of proving the exactness of certain operations of the work. In the first place, two samples of the asbestos used for filtering were tested several times for constancy in weight, after heating to different temperatures; and the greatest loss of any one mat between 130° C. and 700° C. was found to be less than one tenth of a milligram.

In the next place the copper films of experiments 1 and 2 were heated in their crucibles to 500° C. in a stream of pure hydrogen, which was supplied through a curved tube and a perforated lid after the manner of Rose. The platinum rim left unprotected by the copper film was so small that absorption of hydrogen must have taken place only in unweighable quantities. No change in the weight of the copper was observed.

Finally, 0.3530 gram of purest electrolytic copper lost 0.00005 gram on heating to incipient redness in an atmosphere of hydrogen. After dissolving in nitric and sulphuric acids and electrolyzing precisely as usual, the recovered copper weighed 0.35305 gram, indicating a gain of only one tenth of a milligram over the lowest weight previously observed. This gain is not greater than a possible error in weighing; hence, as proof of the accuracy of the electrolytic method and the purity of the materials, the experiment leaves little to be desired.

II. Final Determinations.

Preparation of Cupric Bromide.

In preparing cupric bromide for the final series of experiments it was decided to adopt a wholly new method, namely, the action of excess of bromine upon copper in the presence of water. Pure copper was prepared from a new source, the chemically pure sulphate from a noted German house, by the method which has so often been described.* The salt was freed from a possible trace of bismuth and iron by potassic hydrate in very dilute solution, precipitated from the concentrated filtrate by sulphuric acid, and after many re-crystallizations was finally twice successively decomposed by fractional electrolysis. The resulting copper was a very brilliant and beautiful substance; after being thoroughly washed and dried at 90°, it showed no trace of oxidation on standing three months.

The problem of the preparation of pure bromine has been admirably solved by Stas,† and the method adopted in the present case was largely based upon his, although differing from it in several important particulars. Sixty grams of potassic bromide in dilute solution were completely freed from a trace of iodine by two additions of a small quantity of bromine water, shaking out each time with successive portions of pure carbon disulphide until the two liquids in the separating funnel were alike colorless. After evaporation, the aqueous solution of potassic bromide was mixed with pure dilute sulphuric acid and pure powdered manganese dioxide, and the mixture was subjected to distillation from a glass retort over a water bath, into a glass condenser packed in ice. The manganese dioxide had previously been washed with an aqueous solution of bromine, pure water, hot dilute sulphuric acid, and finally with pure water again until neutral to litmus.

* These Proceedings, xxii. 346, xxiii. 178; this paper, page 199.

† Stas's Untersuchungen, p. 158; Uebergesetzt von L. Aronstein, Leipzig.

Thirty-seven grams of bromine thus prepared were washed twice with water and distilled four times in two very small flasks with long side tubes, the bulbs being alternately packed in ice and immersed in hot water as they alternately served for condenser and retort. The neck of the one serving as the latter was stopped with a glass rod wrapped in fine asbestos, and this bulb was always cleaned and dried before being in its turn used as condenser. In this way bromine may be indefinitely redistilled with very little escape of vapor and without the least inconvenience.

The resulting bromine, although free from iodine, of course still contained an impurity of chlorine, which it is possible to remove by the solution of the whole mass in concentrated aqueous calcic bromide. The required salt was made by the addition of bromine to a mixture of milk of lime with sufficient ammonia water to prevent the formation of oxygen salts of calcium. The clear filtrate from this operation was evaporated to dryness, and the slight excess of lime was neutralized by means of pure hydrobromic acid. The calcic bromide thus formed was freed from iodine in the manner described in the case of the potassium salt, and a very small amount of the pure product served to dissolve all the bromine previously made. The intensely colored, heavy solution parted with some of its bromine on dilution, and with nearly all the remainder on gentle distillation.

Bromine thus prepared is absolutely free from chlorine as well as from iodine. After being twice more distilled, it was taken at once for the preparation of the bromide of copper used in the final determinations of the atomic weight. The combination of the halogen and the metal took place in a cooled flask containing water, and after its completion the slight excess of bromine — added to insure absence of cuprous bromide — was expelled by gentle evaporation to dryness in a glass dish. The nearly normal cupric bromide was then dissolved in a small amount of water, and the strong solution filtered through asbestos in a perforated crucible.

All experiments hitherto tried upon the salt had led to the conclusion that the solid alone loses bromine in the air, the solution being perfectly stable. If therefore it were possible suddenly to crystallize the salt and immediately to wash and dissolve it, we might hope to obtain a normal solution by a method which would insure perfect purity. This result was at last attained by the concentration of the dissolved cupric bromide, barely acidified with pure hydrobromic acid, to the consistency of syrup, — the containing vessel being left wholly undisturbed in vacuo for thirty-six hours. Upon agitation and

cooling with ice, the resulting odorless, black supersaturated solution at once crystallized into a mass of brownish green needles, which were collected on a perforated crucible and washed three times with a very little water. These needles were wholly different in form and appearance from the black scales previously prepared: they were undoubtedly identical with those described by Berthemot and Löwig.* The dilute solution of these crystals deposited only a wholly insignificant amount of the basic bromide upon standing, and this small amount was undoubtedly formed by the rapid current of air drawn through the Gooch crucible. After remaining for more than a week longer there was no sign of further deposition, and the pure liquid was subjected to analysis, with the results given below.

Method of Analysis.

The copper was determined in the same manner as before, except that in experiment 18 the crucible serving as the negative electrode was previously coated inside with a thin film of copper, so that the external conditions before and after the analysis might be the same. The data of this experiment may perhaps make the understanding of the method more clear.

Experiment 18.

		grams.
Weight of glass-stoppered flask with $CuBr_2$ solution	=	93.872
Weight of glass-stoppered flask alone	=	32.289
Weight of solution taken	=	61.583

		Corrected Weights. grams.
Crucible with copper before analysis	=	36.5516
1st drying crucible with additional Cu after analysis	=	37.2260
2d drying crucible with additional Cu after analysis	=	37.22605
Gain of copper film	=	0.6744
Correction to vacuum	=	0.0000
Weight of copper found	=	0.6744

Result.

$$\text{Weight of copper in 50 grams solution} = \frac{50 \times 0.6744}{61.583} = 0.54755$$

In precipitating the bromine from new portions of the solution, not only was the resulting silver bromide weighed, but also the silver

* Berthemot and Löwig, *loc. cit.*

required to form it; and this last value was determined according to two distinct methods. In the first place, the weight of silver required for a given weight of the copper bromide was calculated, and somewhat less than this amount was weighed out and dissolved in nitric acid in the manner before described. The cupric bromide was then cautiously added to the warm dilute solution, and the deficiency of silver made up by very careful titration with a solution containing one gram of silver to the litre.* After noting carefully this first value for the amount of silver required, a slight known excess of the standard solution was added, and the silver bromide was washed, collected, and weighed upon a perforated crucible, as before. The excess of silver in the filtrate was now carefully determined by means of a standard solution of ammonic sulphocyanide, using as a standard of colorimetric comparison solutions containing an equivalent amount of pure copper nitrate and small known amounts of silver nitrate. This second method of determining the amount of silver required to precipitate the bromine is not so accurate as the first, but is of value as a check upon the other. The most complete experiment tried is given in detail, as an example of the method.

Experiments 22 *and* 25.

		grams.
Glass-stoppered flask with $CuBr_2$ solution	=	47.711
Glass-stoppered flask alone	=	21.776
Cupric bromide solution taken	=	25.935

		Corrected Weights. grams.
Amount of silver dissolved (cor. to vac.)	=	0.9639
Amount of silver added in titration	=	0.0001
First value found for required Silver	=	0.9640
0.50 c.c. excess of $AgNO_3$ solution added to filtrate. Silver present	=	0.0005
Total weight of silver used	=	0.9645
Excess of silver was precipitated by 0.07 c.c. NH_4SCN solution. Corresponding silver	=	0.0007
Second value for required Silver	=	0.9638

* For a further description of the method by Prof. J. P. Cooke, see these Proceedings, xvii. 18.

		grams.
Weight of crucible + AgBr dried at 130°	=	18.2516
" " " " 220°	=	18.2516
" Gooch crucible alone	=	16.5738
" AgBr in air	=	1.6778
" " vacuo	=	1.6779

Results.

Weight of silver bromide from 50 grams of solution	=	3.2348
" silver (average) for " "	=	1.8583
" bromine in 50 grams solution	=	1.3765
" Br calculated from AgBr $\left(\frac{80.007}{188.007}\right)$	=	1.3766

Following are the essential data of all the experiments made with the pure solution of crystallized cupric bromide. The results are expressed in the same terms as those given above, and from the combination of these figures a final average value for the atomic weight of copper may be readily deduced.

Final Analyses.

Determination of Copper.

No. of Experiment.	$CuBr_2$ Solution taken.	Copper found (reduced to vacuum).	Copper (red. to vac.) in 50 grams Solution.
	grams.	grams.	grams.
18	61.583	0.6744	0.54755
19	51.955	0.5689	0.54750
		Average . . .	0.54753

Determination of Bromine.

No. of Experiment.	$CuBr_2$ Solution taken.	Silver Bromide found (reduced to vacuum).	Bromine (red. to vac.) in 50 grams Solution.
	grams.	grams.	grams.
20	25.998	1.68205	1.3767
21	25.957	1.6789	1.3762
22	25.935	1.6779	1.3766
		Average . . .	1.3765

Determination of Silver.

No. of Experiment.	$CuBr_2$ Solution taken	Silver required (red. to vac.).		Silver (red. to vac.) for 50 grams Solution.
		Direct Titration.	Sulphocyanide.	
	grams.	grams.	grams.	grams.
23	25.998	....	0.9664	1.8586
24	25.957	0.9645	....	1.8579
25	25.935	0.9640	0.9638	1.8583
		Average . . .		1.8583

Atomic Weight of Copper,

Calculated from the data given above, on the assumption that
Ag : Br = 108.00 : 80.007

							Atomic Weight of Copper. [Br = 80.007.]
I.	From	Experiments	18	and	20	=	63.643
II.	"	"	18	"	21	=	63.664
III.	"	"	18	"	22	=	63.648
IV.	"	"	19	"	20	=	63.636
V.	"	"	19	"	21	=	63.657
VI.	"	"	19	"	22	=	63.641
		Average				=	63.648
							[Ag = 108.00.]
VII.	From	Experiments	18	and	23	=	63.634
VIII.	"	"	18	"	24	=	63.659
IX.	"	"	18	"	25	=	63.645
X.	"	"	19	"	23	=	63.628
XI.	"	"	19	"	24	=	63.653
XII.	"	"	19	"	25	=	63.638
		Average					63.643
		Total average				=	63.645

Highest value = 63.664
Lowest " = 63.628

Greatest variation from mean = ±0.018

If Ag = 108, result previously published = 63.640
If Ag = 108, accepted value (Hampe) = 63.37±

Each analytical result is combined with every other result above, in order that a better idea may be obtained of the variations of the figures. The combination of the averages of the three series of analyses would of course have given the same final average in a much more simple manner. Of the tabulated experiments, No. 23 is the least reliable, for the reasons before given; and rejecting values VII. and X. upon this ground the total average would become 63.648, with a "probable error" of about ± 0.002.

The importance and value of the method of analysis, involving as it does the weighing of the silver used as well as of the argentic bromide formed, must be at once evident. Not only does the method give two wholly distinct classes of results for the atomic weight of copper, but besides this the relative weights of silver and bromine afford the sharpest possible test of the purity of the materials and the accuracy of the work. This method was first used by Professor Cooke in verifying the atomic weight of antimony, and he strongly insisted on the strength of the evidence thus furnished;* although the point has been strangely overlooked by commentators.

Percentage of Silver in Argentic Bromide.

From Experiments 20 and 23	=	57.454
" " 21 " 24	=	57.448
" " 22 " 25	=	57.447
Average	=	57.450–
Average rejecting Exp. 23 as before	=	57.448–
According to Stas	=	57.445

Previous determinations made in this Laboratory by various experimenters have given values ranging from 57.442 to 57.450.

The agreement of the present value of the atomic weight of copper with the result which I previously published in these Proceedings † is a rather remarkable one, especially since the methods of work were wholly different in the two cases. The very slight difference between the preliminary and final results of this paper has already been explained, so that all the experiments which have been tried in this laboratory point to precisely the same figure.

* These Proceedings, xvii. 19; also Huntington on Atomic Weight of Cadmium, these Proceedings, xvii. 28.

† Vol. xxiii. p. 180.

In this connection it is worthy of notice that H. Baubigny,* a recent experimenter upon the atomic weight of copper, dried cupric sulphate at 440° without evidence of the formation of basic salt, and from the weight of copper oxide produced by the ignition of this salt obtained the value 63.47 for the constant under discussion. Baubigny's experiments are too briefly described to be fairly discussed, but their evidence agrees with that of the results of Shaw † in pointing toward a higher value of the atomic weight of copper than that usually accepted.

In the critical review of the present investigation it must be remembered that three distinct methods have been used, the last two being united for the sake of convenience. The chief probable constant error in the first series, given in the two preceding papers, is the chance of a secondary reaction between the copper and the argentic nitrate; but the purity of the silver produced, the absence of the slightest gas evolution during the progress of the chemical action, and the total lack of effect of dilution upon the final result, alike point to the conclusion that no such secondary action took place. In the research upon cupric bromide the chief probable constant error which could raise the observed atomic weight of copper is the presence of basic salt in the solution, but the final crystallization of a neutral salt from an acid solution makes this chance very unlikely. Moreover, the basic salt was shown to be perfectly insoluble in water, and a direct experiment with methyl-orange proved the solution to be normal.

While no experimental knowledge can be said to be even relatively certain, and these with all other results are submitted only to be revised, and perhaps changed, by later experimentation, careful thought seems to show that the presumption is now upon the side of the later determinations of the atomic weight of copper.

During the last few years the atomic weights of antimony ‡ and of cadmium § have also been determined in this Laboratory, and have been referred to the same elements as those used in the present work. A statement of the final comparison might not be uninteresting.

$$Ag : Br : Sb : Cd : Cu = 108.00 : 80.00+ : 120.00 : 112.31 : 63.64.$$

The collective results of the research must now be referred to the various different units of atomic weight usually adopted. Recently,

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* Compt. Rend., xcvii. 854, 906.

† Phil. Mag., 5th Series, xxiii. 138.

‡ J. P. Cooke, *loc. cit.*

§ O. W. Huntington, these Proceedings, xvii. 28.

an investigation * has been conducted here upon the atomic weight of oxygen, and since then many other investigators † have taken up the same subject, all but one ‡ confirming the result of that work. In view of this fact, and also in the light of the recent recalculation of Stas's results, § it seems not out of place to state the value of the atomic weight of copper upon the basis O = 15.87, as well as according to the usual standards.

Atomic Weight of Copper.

If Ag = 108.00	From [Cu : 2 Ag]	Cu = 63.640
	From [$CuBr_2$: 2 AgBr]	Cu = 63.648
	From [$CuBr_2$: 2 Ag]	Cu = 63.643
	Average	= 63.644
If Ag = 107.93	(O = 16.000)	Cu = 63.60
If Ag = 107.675	(Clarke)	Cu = 63.45
If Ag = 107.66	(Meyer and Seubert)	Cu = 63.44
If Ag = 107.06	(O = 15.87)	Cu = 63.09

In conclusion, the writer would express his deep sense of obligation to the kind friends whose interest and advice have so materially assisted the progress of the investigation.

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* Cooke and Richards, these Proceedings, xxiii. 149 and 182. Result, O = 15.87.

† Lord Rayleigh, Roy. Soc. Proc., xliii. 356 (1888); W. A. Noyes, Am. Chem. Journal, xi. 155, xii. 441; E. W. Morley, results as yet unpublished. Also discussions by Crafts, Compt. Rend., cvi. 1662, and many others.

‡ Keiser, Am. Chem. Journal, x. 249. Result, O = 15.95.

§ J. D. Van der Plaats, Chem. News, liv. 186. These results point to a value of oxygen between 15.87 and 15.89.

XIII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON CUPRIC OXYBROMIDE.

By Theodore William Richards.

Presented by the Corresponding Secretary, October 8, 1890.

A careful examination of the basic bromide of copper precipitated by the solution of dried cupric bromide in water being an essential consideration in the preceeding research upon the atomic weight of copper, a quantity of the substance was gradually collected from successive preparations for the purpose of analysis.

The only mention of the preparation of a definite oxybromide of copper in chemical literature is that by Et. Brun,* who obtained a crystalline salt by the slow oxidation of a solution of cuprous bromide in aqueous potassic bromide, as well as by the action of the latter salt upon ammoniacal cupric sulphate. He describes his new preparation as consisting of very small dark green crystals totally insoluble in water, and gives several analyses of different samples which agree with the formula $Cu_2Br(OH)_3$, or $3\,CuO\,.\,CuBr_2\,,\,3\,H_2O$. It seemed very probable that the substance under discussion was identical with this body, although prepared in a very different manner.

The oxybromide so often mentioned in the foregoing description of the research upon the atomic weight of copper crystallizes in very beautiful doubly terminated prisms, which undoubtedly belong to the trimetric system and have the varying habit shown in the accompanying sketch. When precipitated by the rapid addition of water to solid slightly basic copper bromide, the prisms appear as extremely thin plates (Fig. 1), often united in radiating groups; but on more gradual crystallization from stronger brown solutions, the crystals develop nearly equally in all axial directions (Figs. 2 and 3). The only angle even approximately measured with success by means of the microscope was that of the two domes upon each other, giving an

* Compt. Rend., vol. cix. p. 66 (1889). Löwig and Berthemot describe an indefinite substance. Liebig's Handw. Ch., iv. 714; Ann. de Chim. et de Phys., [ii.] xliv. 385.

1. 2. 3.

4.

Magnified 250 diameters.

inclination of about $94\frac{1}{2}°$ between the normals. This value affords us the means of calculating the axial ratio, $x : z = 1 : 1.08$; and the two figures suggest the angle $96° 38'$ and axial ratio $1 : 1.123$ observed in atacamite.* Indeed, the general resemblance in habit and in emerald green color between the two substances is very marked, and has already been noticed by Brun.†

Crystallized cupric oxybromide which has been dried in the air does not lose weight over sulphuric acid. It is of course very soluble in mineral acids and in ammonia, as well as in strong acetic acid. The mode of formation of the salt shows that it must be slightly soluble also in very concentrated solutions of the normal cupric bromide, and that dilution diminishes, or perhaps wholly destroys, this solubility. The proof of its total insolubility in water being of great importance in the preceding research, the following experiment was made.

Two hundred cubic centimeters of water were digested for four days at 25° with a tenth of a gram of very fine crystals of copper oxybromide, the mixture being occasionally shaken. The liquid was then filtered, and thirty cubic centimeters contained in a long tube were tested for copper with ammonia, giving an absolutely negative result. One hundred and thirty cubic centimeters of the same liquid were evaporated to dryness, and the apparently clean dish was rinsed with a few drops of dilute nitric acid, to which was then added an excess of ammonia. An exceedingly faint tinge only of blue was apparent, much less than that produced by one tenth of a milligram of copper under the same circumstances.

Being thus essentially insoluble in water, the oxybromide could hardly be present, even in traces, in the very dilute solution of cupric bromide used for the determination of the atomic weight; but for certainty upon this point the normal state of this solution was tested by experiments with methyl orange. These experiments, which have already been described,‡ settled the question in a wholly satisfactory manner.

* Zepharovitch, Wien. Akad. Sitzungsber., 1871, vol. lxiii. part i. p. 6.

† *Loc. cit.*

‡ This volume, page 201.

The salt is decomposed by continued boiling with water into the normal bromide and a dark insoluble compound of uncertain composition. Brun has already pointed out the fact that the crystals are quite decomposed when heated to 250°.

On account of the very small amount of substance at hand, the analysis was undertaken with all possible care.

I. 0.20003 gram of copper oxybromide yielded, on evaporation with nitric and sulphuric acids and subsequent electrolysis, 0.09823 gram of metallic copper.

II. 0.0828 gram of copper oxybromide yielded, on solution in ammonia, acidification with nitric acid, and precipitation by silver nitrate 0.0606 gram of argentic bromide.

Analysis of Cupric Oxybromide.

	Theory, $Cu_2(OH)_3Br$.	Found. I.	Found. II.	Average of Brun's results.
Copper	49.27	49.11		49.19
Bromine	30.98		31.15	31.05

The results agree with the theoretical as well as could be expected, considering the small quantities of substance used.

By the very slow oxidation of cuprous bromide, kept under water in the dark for six months, groups of emerald green radiating prisms over a tenth of a millimeter in length were obtained (Fig. 4), which by their terminal angles, color, and general appearance showed themselves to be identical with the compound whose analysis has just been given. The amount of these crystals was so small that it was impossible to determine their percentage composition, but there can be no doubt of its agreement with that given above. The crystalline salt was also obtained by the long continued action of cupric oxide upon a strong solution of cupric bromide.

It will be seen that the formula

$$Cu_2(OH)_3Br \text{ (or, } 3\,CuO \,.\, CuBr_2 \,.\, 3\,H_2O)$$

does not exactly correspond to that of any one of the known oxychlorides, containing only three fourths as much water as atacamite ($3\,CuO \,.\, CuCl_2 \,.\, 4\,H_2O$). It is a noteworthy fact, however, that many of the more definite basic salts of copper contain, as these do, three molecules of copper oxide to every single molecule of the normal compound.

XIV.

ON THE COMPOSITION OF CERTAIN PETROLEUM OILS, AND OF REFINING RESIDUES.

By Charles F. Mabery.

Presented October 8, 1890.

In an examination of crude Lima oil that I had occasion to make in the early development of the Ohio oil fields in 1885, I observed the peculiar penetrating odor of the sulphur compounds; and while they were present in all fractions during distillation, I noted that they collected principally in the portions with higher boiling points, between 200° and 300°. A systematic examination of the oil was soon undertaken for the purpose of ascertaining the form of the sulphur compounds; but little was accomplished when the work was interrupted by a destructive fire, and it was not resumed until two years later.

In published accounts of the composition of petroleum oils I have found very few allusions to the presence of sulphur, and those that appear are limited to the products of distillation. Hagar * found carbonic disulphide in petroleum ether, but none in burning oil. H. Vohl † reported sulphur in considerable quantities as sulphuric acid in numerous samples of crude (Roh) petroleum. But from the data given and allusions to the products as burning oils, they had undoubtedly been refined with the aid of sulphuric acid. Much difficulty has been experienced in the removal of sulphur from the distillates of Ohio oil, and consequently few if any of the commercial products are entirely free from sulphur, while it is frequently present in considerable quantities.

This paper contains a description of results thus far obtained, of which the following is a summary: —

1. The separation and identification of methyl, ethyl, normal propyl, iso- and normal butyl, pentyl, ethylpentyl, and hexyl sulphides, which are present in crude Ohio petroleum.

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* Jahresb. Liebig, 1867, p. 947, Aus Pharmac. Centralle.

† Ibid., 1875, p. 1053; Dingl. Journal, ccxvi. 47.

2. The separation of certain sulphides that do not correspond in boiling points nor in composition with any sulphides hitherto described, which will be further examined.

3. The separation of certain sulphur free oils apparently unsaturated that also require further study.

I am not aware that these alkyl sulphides have hitherto been identified as natural products.

I. THE SULPHUR COMPOUNDS IN OHIO PETROLEUM.

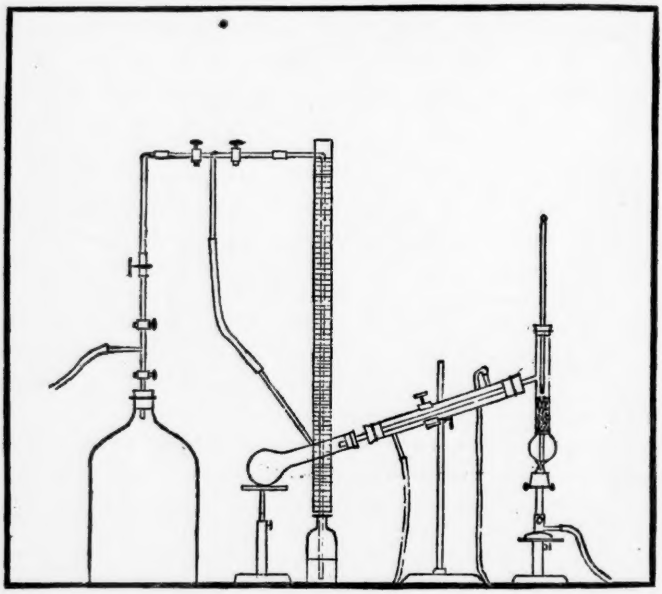
By Charles F. Mabery and Albert W. Smith.

When the various distillates from Ohio oils are agitated with concentrated sulphuric acid, the sulphur compounds are partially removed in combination with the acid. By neutralizing the acid solution with plumbic carbonate, filtering, and evaporating carefully, lead salts soluble in water are obtained that are easily decomposed by heat with the formation of plumbic sulphide. If the acid solution is neutralized with calcic carbonate or calcic hydrate, unstable calcium salts are formed that are readily decomposed by distillation with steam, which carries over the sulphides without decomposition.

In applying a mode of separation from the crude oil of the sulphur compounds based upon these observations, we procured fifty litres of what is technically known as sludge acid that had recently been used in refining Lima burning oil, and after dilution we neutralized it in the cold with slaked lime and distilled the mixture of solution and solid with steam. We thus obtained 2,270 grams of the sulphur oil that was colorless when freshly distilled, and entirely free from hydric sulphide. Analysis showed that it contained 14.97% of sulphur with a specific gravity at 16°.5 of 0.9245. Analyses of samples of crude Ohio oils from different localities have given on the average about 0.50% of sulphur.

Distillation under atmospheric pressure of the oil distilled with steam produced such serious decomposition that we were forced to conduct all fractional separations with diminished pressure; but since the decomposition was inappreciable at tensions reduced to 150 mm., this involved but little additional labor, except in the inconvenience of maintaining the required tensions with the use of common corks without lutings, which became necessary on account of the solvent action of the oil. The fractional distillations were carried on in the apparatus represented in the accompanying diagram; while it contains no features not hitherto described, it may serve to illustrate how such

an apparatus can readily be arranged to work satisfactorily from material always at hand in the laboratory. Hill's * application of the Hempel device, which consists in supporting glass beads in the neck of the distillation flask on a piece of glass rod with one end



enlarged, is a means of saving much time in a long series of separations. The receiver is simply a second distillation flask. This form of manometer was most convenient, since hydric sulphide was evolved to a certain extent, and, the manometer tube becoming discolored by mercuric sulphide, occasionally it had to be cleaned. In exhausting the apparatus we used an ordinary glass water-pump, and to avoid loss of time in disconnecting the flask, a ten-litre bottle was inserted as a reservoir with stopcocks necessary for continuous action, and a nipper tap with an enlarged thumbscrew was also attached for closely adjusting the pressure.† With this apparatus there is scarcely more

* These Proceedings, xxiv. 342.

† We were unable to use the convenient device of Anschütz for maintaining constant tensions, since the current of air produced considerable decomposition of the oils.

interruption to continuous distillation than at atmospheric pressure. From 1,000 grams of the oil at the end of the sixth distillation, with a tension of 150 mm., the following weights were obtained: —

Temperatures .	−70°	70–80°	80–90°	90–95°	95–100°	100–105°
Grams . . .	12	8.5	16	16	26	20.5
Temperatures	105–110°	110–115°	115–120°	120–125°	125–130°	130–135°
Grams . . .	31	30	83	47.5	59	66
Temperatures	135–140°	140–145°	145–150°	150–155°	155–160°	+160°
Grams . . .	69	56.5	75	36	40.5	230
		Total		921.5		

At the end of the twenty-second distillation, with the tension reduced to 100 mm., the products collected to a large extent within well defined limits of temperature and several determinations of sulphur gave the following results: —

Fraction	−76°	80–90°	98–101°	135–145°	148–155°	185–200°
Per cent sulphur . .	2.60	7.34	18.23	15.52	16.44	14.21

All fractions containing sulphur gave precipitates with alcoholic and with aqueous mercuric chloride, which were either crystalline, or, with the less volatile products, thick viscous oils. The latter usually became solid on standing, or when crystallized from benzol. As a qualitative test for sulphur, we depended upon the exceedingly delicate nitro-prussid reaction, which was especially serviceable in separating sulphur oils from those containing no sulphur. The platinum compounds R_2SPtCl_4 were readily formed with chlorplatinic acid with evolution of hydrochloric acid. With bromine all fractions united with great energy with the formation of oils heavier than water. These reactions suggested the presence of sulphides, or with sulphur free oils the reaction with bromine indicated unsaturated hydrocarbons.

When distilled at temperatures above 140° atmospheric pressure, the oils became thick and dark in color, and hydric sulphide was freely evolved. Since at lower temperatures the decomposition was slight, the fractional separation of the products collected below 101° ($P = 100$ mm., see above) was carried further. The products thus collected below 125° united readily with concentrated hydrobromic acid when heated, forming oils heavier than water. The fraction $80-90°$ was nearly all converted into the heavy addition product, and the fraction $90-100°$ separated into two products, one heavier

and one lighter than water, the latter in somewhat smaller quantity than the former. The addition product from the fraction 80 – 90° possessed the characteristic odor of the substituted paraffine hydrocarbons, and upon analysis it gave a percentage of bromine corresponding to monobromheptylen.

0.1850 gr. of the substance gave 0.1116 gr. AgBr.

	Calculated for $C_7H_{15}Br$.	Found.
Br	46.93	46.57

With bromine this product united with a violent reaction, and the resulting oil gave a percentage of bromine required for dibromheptylen.

0.1938 gr. of the substance gave 0.2797 gr. AgBr.

	Calculated for $C_7H_{14}Br_2$.	Found.
Br	62.01	61.42

This fraction therefore consists principally of a heptylen, and it is probably identical with the heptylen obtained by Pelletier and Walthier from the coal oil of Amiano.*

Upon the addition of alcoholic mercuric chloride to fraction 110–125° atmospheric pressure, a finely crystalline precipitate was formed that contained a percentage of mercury required for methyl sulphide.

0.3156 gr. of the mercury compound gave 0.2214 gr. HgS.

	Calculated for $(CH_3)_2SHgCl_2$.	Found.
Hg	60.06	60.47

The fraction 125 – 135° also gave a crystalline precipitate with alcoholic mercuric chloride, which after crystallization from benzol gave a percentage of mercury corresponding to ethyl sulphide.

0.5056 gr. of the mercury compound gave 0.3122 gr. HgS.

	Required for $(C_2H_5)_2SHgCl_2$.	Found.
Hg	55.40	55.42

Although the boiling points of the oils from which these mercury addition products were separated were considerably higher than those of the sulphides to which the mercury determinations correspond, these oils consisted to a certain extent of hydrocarbons which were subsequently found to contain no sulphur. The higher fractions gave with mercuric chloride oily addition products which became

* Berz. Jahresb., xxi. 470.

crystalline after washing with alcohol, and separation from hot benzol. The addition product from fraction 150 − 155° gave 53.33% Hg; calculated for $(C_3H_7)_2SHgCl_2$, 51.41% Hg. It was therefore probably a mixture of propyl and butyl sulphides. From fraction 155 − 160° the addition product with mercuric chloride gave upon analysis 49.44% Hg; required for $(C_7H_9)_2SHgCl_2$, 47.96% Hg. It therefore still contained a lower sulphide. On account of the small quantity that we obtained of these products, we were unable to separate them more completely.

We will next describe in detail the separation of the various sulphides.

Methyl Sulphide.

Further attempts to separate the lower sulphides were made from the crude naphtha distillate. We procured 250 litres of crude naphtha from Findley oil that nearly all distilled below 150°, and agitated it thoroughly in quantities of five litres each, with aqueous mercuric chloride. The heavy flocculent precipitate that separated was subjected to heavy pressure in a screw press, dried, and decomposed by hydric sulphide in presence of alcohol. For the decomposition of considerable quantities of the mercury addition product, vigorous agitation was necessary, and the mercuric sulphide invariably separated in the red modification. After filtration the alcoholic solution of the oil was diluted with water, the oil collected in a separatory funnel, washed, dried, and submitted to fractional distillation. It was nearly colorless, with a specific gravity at 20° of 0.8543. Under atmospheric pressure the decomposition was less marked than in the case of the oil extracted with sulphuric acid. A small quantity of the oil was collected below 50° that gave a percentage of sulphur corresponding to methyl sulphide.

0.1800 gr. of the oil gave by the method of Carius 0.6672 gr. $BaSO_4$.

	Calculated for $(CH_3)_2S$.	Found.
S	51.61	50.89

Between 60° and 80° the quantity of distillate was too small to prove the presence of methylethyl sulphide. Results of analysis were intermediate between the requirements for methyl and ethyl sulphides, but not sufficiently close for methylethyl sulphide. On account of the great amount of labor involved in the separation of these volatile oils, no further attempts were made to identify this sulphide, especially as its presence was regarded as doubtful.

Ethyl Sulphide.

After long continued fractional distillations, we succeeded in obtaining a product distilling between 88° and 92° that gave a percentage of sulphur corresponding to ethyl sulphide.

0.16.32 gr. of the oil gave 0.4183 gr. $BaSO_4$.

	Calculated for $(C_2H_5)_2S$.	Found.
S	35.55	34.86

Ethylpropyl Sulphide.

At several points between 91° and 130°, the boiling points respectively of ethyl and propyl sulphides, distillates collected in considerable quantities. A fraction that distilled tolerably constant at 110−112° contained a percentage of sulphur required for ethylpropyl sulphide.

0.2445 gr. of the substance gave 0.5396 gr. $BaSO_4$.

	Calculated for $\left\{ \begin{matrix} C_2H_5 \\ C_3H_7 \end{matrix} \right\} S$.	Found.
S	30.77	30.31

The platinum salt was formed by the addition of alcoholic chlorplatinic acid, and it gave on analysis the required percentage of platinum.

0.3240 gr. of the substance gave 0.1158 gr. Pt.

	Calculated for $2\,(C_5H_{12})_2S \,.\, PtCl_4$.	Found.
Pt	36.01	35.75

The quantity of this sulphide that we obtained was insufficient for complete examination, and further study of it, as well as of other fractions of low boiling points, must therefore be postponed until we can secure a larger supply of material.

Normal Propyl Sulphide.

All attempts to isolate isopropyl sulphide were unsuccessful; very little of the distillate collected between 115° and 125°, and analysis showed that it could not be the isopropyl compound that boils at 120°. The fraction 115−120° gave 29.29% S, and the fraction 120−125°, 28.52% S; calculated for $(C_3H_7)_2S$, 27.12% S. Analysis of platinum salts of these fractions gave similar results. Normal propyl sulphide was readily identified in the fraction 127−132°, which collected in larger quantities.

0.0443 gr. of the substance gave 0.0880 gr. $BaSO_4$.

Calculated for $(C_3H_7)_2S$.	Found.
27.12	27.44

The presence of propyl sulphide was further shown by analysis of the platinum salt.

I. 0.1720 gr. of the salt gave 0.0600 gr. Pt.
II. 0.1309 gr. of the salt gave 0.0457 gr. Pt.
III. 0.0930 gr. of the salt gave 0.0329 gr. Pt.

	Calculated for $2(C_3H_7)_2S \cdot PtCl_4$.	Found. I.	II.	III.
Pt	34.26	34.10	34.92	35.15

Analyses II. and III. were made of preparations from fraction 80–90° (P = 150 mm.) that were obtained in fractioning the oil from the sulphuric acid extract. This oil contained only very small quantities of propyl sulphide, or of other lower homologues. It consisted mainly of higher sulphides and of sulphur free oils. The presence of heptylen has been described, and nearly all fractions contained sulphur free oils that united readily with bromine, and those of lower boiling points with hydrobromic acid. The sulphides were separated by dissolving the oil in alcohol, and adding a small excess of alcoholic mercuric chloride. An aqueous solution precipitates the sulphides, but it is apt to carry down the sulphur free oil. The precipitates were usually in the form of a thick viscous mass, although with care they could be obtained crystalline. They were washed with alcohol, and decomposed by hydric sulphide in presence of alcohol. The filtered alcoholic solution was diluted with water, and the sulphide that separated was washed free from hydric sulphide, dried, and again submitted to fractional distillation for analysis.

Upon dilution of the alcohol from the precipitation by mercuric chloride, an oil separates that is lighter than water, and with an exceedingly disagreeable odor. These oils unite readily with bromine and with hydrobromic acid, and they contain no sulphur. Whether they are decomposition products resulting from the action of sulphuric acid upon the sulphur oils, or are normal constituents of the crude petroleum, we have not fully determined. But since the sludge acid showed very little indication of decomposition, it seems probable that the sulphur free oils are abstracted by sulphuric acid during the process of refining.

The composition of the fractioned sulphides before and after treatment with mercuric chloride may be shown by the effect on the

U of M

percentage of sulphur. The fraction 135 − 140° (P = 150 mm., B. P. = 185 − 190°, P normal) gave 15.40% S. After treatment with mercuric chloride as described above, analysis showed 20.37% S.

The higher sulphides were all obtained from fractions of the oil that was extracted from sludge acid. Those of medium boiling points may be separated in smaller quantities from naphtha distillates by mercuric chloride, which has the advantage that the sulphides are uncontaminated by other products. But this method is exceedingly laborious, and the yields are small. We have in mind a modification that works successfully with small quantities of the mercury addition product. It includes recovery of the mercury by conversion of the sulphide into the sulphoxide.

Ethylpentyl Sulphide.

After the twenty-second distillation (page 221), a sulphide was obtained from fraction 95 − 100° (P = 100 mm.) through the mercury compound that distilled without decomposition at 156 − 160°. It gave, upon analysis, a percentage of sulphur required for ethylpentyl sulphide (B. P. 158 − 159°).

I. 0.2629 gr. of the oil gave 0.4516 gr. $BaSO_4$.

II. 0.1169 gr. of the oil gave 0.2056 gr. $BaSO_4$.

	Calculated for $\left\{\begin{matrix} C_2H_5 \\ C_5H_{11} \end{matrix}\right\}$ S.	Found. I.	Found. II.
S	24.24	23.59	24.15

Isobutyl Sulphide.

The mercury addition product from fraction 110 − 115° (P = 100 mm.) was decomposed with hydric sulphide and the alcoholic solution diluted with water. After drying over calcic chloride, the oil thus obtained distilled at 170 − 176°, which corresponded to the boiling point of isobutyl sulphide (172°) and its composition was further shown by a determination of sulphur.

0.1750 gr. of the oil gave 0.2760 gr. $BaSO_4$.

	Calculated for $(C_4H_9)_2S$.	Found.
S	21.92	21.66

Normal Butyl Sulphide.

The fraction 117 − 125° (P = 100 mm.) gave an addition product with mercuric chloride from which an oil was obtained that distilled at 180 − 185° (B. P. of normal butyl sulphide = 182°), and the percentage of sulphur indicated butyl sulphide.

MnU

I. 0.1633 gr. of the oil gave 0.2657 gr. $BaSO_4$.
II. 0.2929 gr. of the oil gave 0.3236 gr. $BaSO_4$.

	Calculated for $(C_4H_9)_2S$.	Found. I.	II.
S	21.92	22.35	21.07

Butylpentyl Sulphide.

An inspection of the weights collected at different temperatures given on page 220 will show a tendency of the distillates to collect at certain temperatures, and this is especially evident in the fraction 135° − 140°. As the distillation proceeded, the fractions at these points increased in quantity, and, so far as examined, each of them corresponded to a definite sulphide. From the fraction 135° − 140° an oil was obtained by decomposition of the addition product with mercuric chloride that distilled at 185° − 190° (Bar. = 740 mm.) and the percentage of sulphur corresponded to butylpentyl sulphide.

I. 0.2509 gr. of the oil gave 0.3721 gr. $BaSO_4$.
II. 0.2676 gr. of the oil gave 0.3925 gr. $BaSO_4$.

	Calculated for $\left\{\begin{matrix} C_4H_9 \\ C_5H_{11} \end{matrix}\right\}$ S.	Found. I.	II.
S	20.00	20.37	20.14

It is hardly probable this product was a mixture of butyl and pentyl sulphides, since it was obtained at different times after prolonged distillation. It will be further examined.

Pentyl Sulphide.

This sulphide was separated from the fraction 150 − 155° (P = 100 mm.) by conversion into the mercury compound and decomposition with hydric sulphide. Different preparations from independent fractions distilled with very little decomposition at 205 − 210° (Bar. = 745.5 mm.), which is somewhat lower than the boiling point assigned to pentyl sulphide (216°). But from the results of analysis there can be no doubt as to the composition of this sulphide.

I. 0.1987 gr. of the oil gave 0.2717 gr. $BaSO_4$.
II. 0.2723 gr. of the oil gave 0.3716 gr. $BaSO_4$.
III. 0.2844 gr. of the oil gave 0.3902 gr. $BaSO_4$.

	Calculated for $(C_5H_{11})_2S$.	Found. I.	II.	III.
S	18.39	18.75	18.74	18.85

It is quite probable that the low boiling point was due to the presence of a very small quantity of a lower sulphide, since the

sulphur determinations are somewhat higher than the percentage required for pentyl sulphide.

Hexyl Sulphide.

From the fraction 160 – 170° (P = 100 mm.) by precipitation with mercuric chloride and decomposition with hydric sulphide a light yellow oil was obtained that distilled with some decomposition at 225 – 235°, and it gave a percentage of sulphur required for hexyl sulphide.

0.3110 gr. of the oil gave 0.3531 gr. $BaSO_4$.

	Calculated for $(C_6H_{13})_2S$.	Found.
S	15.84	15.59

At least one third of the original oil distilled above the boiling point of hexyl sulphide, but with considerable decomposition even under diminished pressure. It consisted to a very large extent of sulphides, but we have not attempted to separate them for identification.

In order to satisfy any doubt as to whether these sulphides are contained in the crude petroleum, we distilled several litres under diminished pressure to avoid decomposition, and extracted portions of various distillates with sulphuric acid, and other portions with aqueous mercuric chloride. The oils, separated from the acid solution and from the mercuric chloride addition product, resembled in all respects the products previously described. From the distillate corresponding to 150 – 300° atmospheric pressure, or to the best grades of burning oil, by agitation with aqueous mercuric chloride, the characteristic heavy precipitate was formed, and the oil obtained from it contained 19.72% sulphur and gave all the reactions for sulphides. In separating sulphides from oils extracted with sulphuric acid, we have frequently obtained small quantities of a product with a penetrating odor resembling that of turpentine; and at other times, oils containing no sulphur with an odor characteristic of certain ethereal oils, such as peppermint or pennyroyal. But we have not yet obtained these oils in quantity sufficient for examination.

The study of Ohio oils will be continued, and the investigation will include an examination of oils from other localities for sulphur compounds, and also the composition of other acid residues and by-products obtained in refining petroleum oils.

XV.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

A NEW METEORIC IRON FROM STUTSMAN COUNTY, NORTH DAKOTA.

By Oliver Whipple Huntington, Ph. D.

Presented December 10, 1890.

I lately received, through the kindness of Professor Alfred J. Moses, of the School of Mines, Columbia College, an undescribed specimen of meteoric iron of special interest.

It was found in November or December, 1885, during the construction of the James River Valley branch of the Northern Pacific Railroad, about fifteen or twenty miles southeast of Jamestown, Stutsman County, North Dakota.

It was found by one of the workmen, who gave it to Mr. John W. Gilbert, conductor of the construction train, saying he had taken it out of a slanting hole within five feet of the track. It is now impossible to find the exact locality, since the road was laid through new country, away from wagon roads or trails, and no particular attention was given to the matter at the time.

The specimen weighs 4,015 grams, and is of peculiar shape and appearance. As is well known, most of the meteoric irons which have been collected and recorded appear to be angular fragments of larger original masses; but the iron under discussion appears like a thick scale or splinter, which must have been blown off from the spherical surface of a large body, since the entire specimen is curved. Through the centre runs quite a thick zone which gradually narrows down to sharp edges on all sides, these edges forming, however, a continuous curved outline, with no jagged points or projections, as shown in Figures 1 and 2, reproduced from photographs of the specimen. The greatest length of the splinter is 26 cm.; greatest width 13 cm., but only 3.7 cm. through the thickest central portion, while the average thickness is not half as great. Furthermore, the exterior shows two utterly different surfaces. The convex side, which

must have formed the crust of the original mass, appears quite smooth except for a succession of small pittings, in the centre of each of which appears a little drop of chloride of iron, making it rust rapidly, and so causing little scales to flake off, thus possibly producing the depressions. This surface is the one shown in Figure 1. On the other hand, the concave side of the specimen is characterized by a vesicular structure not unlike certain furnace specimens, some of the cavities being about two centimeters across and nearly as deep. These cavities seem to be distributed with some regularity in three more or less parallel zones across the shorter dimension of the surface. Figure 2 is intended to show this feature of the specimen. These cavities appear to have no connection with the pittings of the surface, and are different from anything I have observed in the meteoric irons which have come under my notice. They seem to suggest an evolution of gas from the material in process of cooling, which may have been the cause of the splitting off of the specimen from the original mass.

In order to examine the structure, the iron was sawed through the thickest part by means of a toothless band saw fed with emery; but when the cut had come within an inch of the opposite edge, the remaining portion was forcibly broken in order to bring out the characters of the fracture, when the iron showed a somewhat new feature. The metal was so malleable, that, though the connecting surface had an area of a square inch, the two portions could be bent and twisted quite readily, almost like masses of lead, but it was very difficult to make it break; and when at last the two portions separated, the fracture showed no crystalline structure whatever, but only irregularly curved surfaces like a perfectly plastic material.

The author has shown in a previous paper,* that even the most malleable meteoric irons, when broken under the hammer, usually exhibit very striking peculiarities of cleavage parallel to certain crystalline faces, and that even in such compact irons as those of Bates County and Coahuila large cleavage crystals could be broken out from the mass; and the characters exhibited by the cleavage were suggested as a possible means of distinguishing different meteoric irons where other methods proved insufficient. Hence the fracture of the Stutsman County iron was a complete surprise, and in order to study it further it was mounted in the vice and broken in various directions, but no trace of cleavage could be produced. When the

* These Proceedings, vol. xxi. p. 478, May 12, 1886.

thin edge was held in the vice, the mass could be readily bent back and forth with the hand, and it invariably broke like a soft semi-solid material. Moreover, the iron was so malleable that it could be readily rolled out into thin ribbon in the cold. Such extreme malleability and the peculiar fracture separate this iron from all others with which I am familiar.

One would naturally expect from the foregoing characteristics that the Stutsman County iron would show no crystalline structure when acted on by dilute nitric acid, but when the cut surface was polished and etched, it gave typical Widmanstättian figures, showing how-

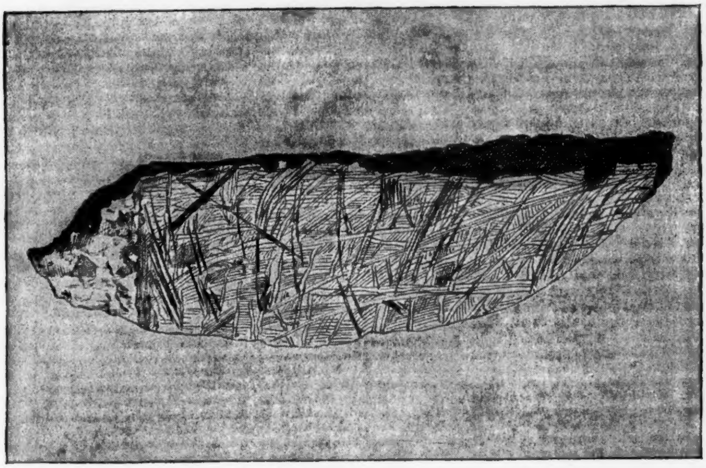


Fig. 3.

ever plates not over one millimeter thick, closely interlaced, frequently bent, and occasionally intersected by linear inclusions of troilite two or three centimeters long. The figures closely resemble those of Oldham County, and are not unlike those of Obernkirchen, being so closely interlaced as to appear somewhat confused until carefully examined. On first etching the iron, there is a blackening of the surface, as in the case of steel, which gives for the moment prominence to the figures; the superficial deposit is easily rubbed off, however, when the surface appears bright and shining, but the figures indistinct. Figure 3 is copied from a drawing of the etched surface, and shows at one end the peculiar fracture already described.

I have not yet been able to make a thorough examination of the

chemical composition of the iron, but hope to do so later, in connection with some other meteorites. A preliminary analysis, however, gave the following results.

Iron	90.24
Nickel	9.75
Phosphorus	.05
Copper	trace
	100.04

A specimen of the iron weighing nearly two grams was examined for sulphur, but showed no trace.

The points of special interest in the Stutsman County iron are: —

First, that it was found at the bottom of a slanting hole rendering it probable that it belonged to a comparatively recent fall.

Secondly, its peculiar shape, making it appear like a scale split from the surface of a spherical body.

Thirdly, its extreme malleability and peculiar fracture.

Lastly, the vesicular structure of a portion of the surface.

XVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XXXVI. — ON THE INFLUENCE OF THE STRENGTH OF THE MAGNET IN A MAGNETO TELEPHONE RECEIVER.

BY CHARLES R. CROSS AND HARRY E. HAYES.

Presented November 12, 1890.

THE present investigation is a continuation of the research described in a paper by Messrs. Cross and Williams, previously published in these Proceedings (vol. xxiv. p. 113). With a magneto telephone transmitter it was found that, as the strength of the magnet was increased, the induced current produced by a definite motion of the diaphragm increased quite rapidly to a maximum, and then gradually decreased. With diaphragms of different thickness it was found that, as the field necessary to saturate the diaphragm increased in strength, the maximum value of the induced current occurred with a greater strength of field, and also that the value of this maximum current increased with the thickness of the diaphragm, other things remaining the same. One series of measurements, however, whose results are shown in curve No. 23, Figure 2, of that article, seemed to be at variance with this conclusion, a discrepancy which was explained on the supposition that the supports holding the cam-rod by which the diaphragm was thrust forward yielded to a material extent with the thicker and stiffer diaphragm, which, by lessening the motion of this, would produce the observed result of a diminished current.

A series of measurements was first made in order to ascertain whether the above conclusion was correct. The apparatus employed was identical with that described in the previous article referred to, but the supports carrying the cam-rod were much increased in rigidity. The same diaphragms were employed as in the earlier experiments. The results were such as to show that the explanation of the discrepancy suggested was the true one, as will be seen on an examination of Tables I., II., and III. The diaphragms used were of iron, and of

the same thickness as in the previous experiments, viz. Nos. 21, 22, and 23, B. W. G., corresponding to a thickness of 0.032 in., 0.027 in., and 0.024 in., respectively.

TABLE I.

DIAPHRAGM, SHEET IRON, No. 21.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.0	.384	105.7
.070	19.0	.441	102.0
.119	38.0	.492	101.3
.158	49.5	.584	101.0
.202	64.0	.637	98.0
.246	77.7	.740	92.3
.292	93.3	.900	88.5
.344	99.0		

TABLE II.

DIAPHRAGM, SHEET IRON, No. 22.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.0	.380	97.5
.070	19.5	.425	96.8
.105	35.5	.456	96.7
.141	39.7	.514	94.0
.176	47.0	.577	88.0
.222	63.3	.700	84.3
.258	73.7	.781	76.5
.306	86.0	.916	71.5
.344	94.0		

TABLE III.

DIAPHRAGM, SHEET IRON, No. 23.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.0	.325	86.3
.070	15.5	.364	90.0
.123	30.5	.492	82.5
.155	42.3	.558	76.0
.194	53.8	.637	66.5
.236	65.0	.700	61.5
.268	75.7	.900	50.8

It was feared, however, that further difficulty might be met with from yielding of the supports of the cam-rod when heavy diaphragms were used, so that a modification of the apparatus was thought to be desirable. The cam-rod was therefore provided with a brass diaphragm-holder, so that the diaphragm, being carried by this, was moved bodily forward by the longitudinal motion of the cam-rod. A series

of observations made with the same diaphragms used in the experiment last described gave the results shown in Tables IV., V., and VI., which are in substantial accord with those reached with the earlier form of the apparatus as given in Tables I., II., and III. From these tables the curves shown in Figure 1 were constructed. The induced currents are represented by abscissas, the strengths of the field by ordinates.

TABLE IV.

Diaphragm, Sheet Iron, No. 21.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	1.7	.620	124.3
.123	28.3	.649	118.3
.194	44.0	.700	111.0
.262	55.8	.787	102.9
.306	63.9	.862	96.5
.384	82.3	.976	88.5
.466	98.5	1.213	68.5
.554	118.5		

TABLE V.

Diaphragm, Sheet Iron, No. 22.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.5	.514	86.7
.125	22.5	.596	91.4
.191	36.3	.654	89.0
.268	45.3	.716	81.5
.302	52.8	.807	77.0
.325	56.9	.983	69.3
.420	72.3	1.065	56.3
.466	84.3	1.235	52.3

TABLE VI.

Diaphragm, Sheet Iron, No. 23.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.0	.488	90.5
.126	20.8	.577	87.5
.134	34.9	.654	80.3
.266	43.8	.716	72.0
.302	52.4	.784	57.4
.337	62.5	.888	43.2
.412	83.0	1.036	30.5
.449	89.3	1.235	24.5

The numbers 21, 22, 23, affixed to the curves of Figure 1, indicate the thickness of the corresponding diaphragms by their gage number (B.

W. G.). The curves show that with the diaphragms Nos. 21, 22, 23, the maximum induced currents were 124, 93, 91, respectively, corresponding to relative strengths of field 61, 56, 49. The results reached in the earlier article are fully confirmed by these figures, which prove that, within the limits of the experiments, the maximum current is greater, and is reached with a stronger field, as the diaphragm is thicker.

An examination of the curves of Figure 1 shows that the point of maximum current is less distinctly marked with the thinner dia-

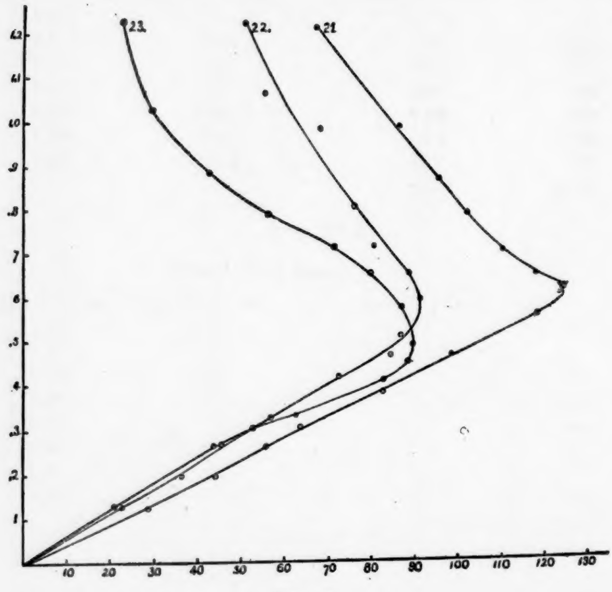


FIG. 1.

phragms than with the thickest. We are inclined to believe this to be an accidental peculiarity, due to a slight yielding of the diaphragm, which was fastened at its edges and which when thin would tend to bulge towards the magnet, thus causing its whole motion to be performed in a stronger field, and so giving rise to a stronger induced current than would otherwise be the case. An extremely slight displacement of this kind will produce a noticeable difference in the resulting induced current. This effect may also have acted to diminish somewhat the difference between the maximum current obtained with

the two thinnest diaphragms, which difference is much less than the difference between the maximum current with the two thickest ones.

Care was taken in all the experiments described in this paper that the magnet of the apparatus should be far below saturation, even with the strongest magnetizing currents which were used.

Our experiments were next directed to a study of the conditions operative in the magneto receiver, and particularly to ascertain the effect of a varying degree of magnetization in the magnet of the receiver upon the change in its strength when subjected to the action of a slight current of the same order of magnitude as that used in telephony.

The apparatus employed consisted of a core of soft Norway iron, six inches long and a quarter of an inch in diameter, and provided with a suitable magnetizing coil. A diaphragm was placed opposite one end of the core, as in the usual magneto receiver. This end of the core also carried two coils of fine wire, like the ordinary telephone magnet coil, one having a resistance of about 130 ohms, the other of about 190 ohms. The former of these coils was connected with a storage cell, a fixed resistance, and a key. By means of this apparatus a current of suitable magnitude could be caused to traverse the coil, which evidently corresponds to the coil of the ordinary receiver, and which we have called the "line coil." The effect of this current will be slightly to increase or decrease the magnetization of the bar magnet, as in the receiver itself. The second fine wire coil is a "measuring coil," and is connected in circuit with a ballistic galvanometer, from whose deflection when a current was sent through the first fine-wire coil the effect of this current on the magnet of the receiver could be determined. A magnetometer arranged in the usual manner showed the relative strength of the field of the receiver magnet under differing conditions of magnetization.

The observations consisted in adjusting the magnitude of the current through the magnetizing coil so as to give a certain deflection of the magnetometer needle. The magnetizing circuit included a suitable resistance coil, by the use of which any desired current could readily be secured. The key was then pressed, so that a certain current flowed through the line coil. The proper value was given to this current by means of a rheostat. The induction occurring in the measuring coil gave rise to a transient current through this circuit, the value of which was known from the deflection of the needle of the ballistic galvanometer included in it. Of course the key had to be kept down until the observation was completed, and it was also neces-

sary, on account of the self-induction of the measuring circuit, always to read either on opening or on closing the key. In our experiments the latter alternative was chosen.

The results were plotted as previously by using the relative strength of the field as expressed by tangents of the magnetometer deflections as ordinates, and the induced currents in terms of an arbitrary unit as abscissas. The deflection of the ballistic galvanometer used was

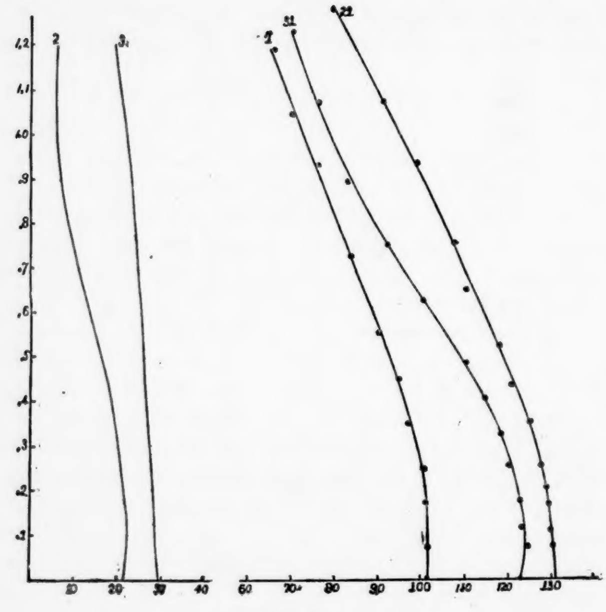


FIG. 2.

proportional to the strength of the transient current passing through its coils.

A series of observations was first made with the diaphragm removed, in order to study the deportment of the core alone under varying degrees of magnetization. The results are given in Table VII., and are shown graphically in Curve 1, Figure 2. It appears from these, that with increasing magnetization of the core the induced current remains nearly constant for a time, and then diminishes rapidly and at an increasing rate, which afterwards becomes nearly constant, a result which would be anticipated from the corresponding diminution in

the magnetic change which a small current in the line coil would produce.

The current which traversed the line coil was six milliamperes, a value which was used in most of the measurements, it having been found by trial that the general character of the results was the same as when a smaller line current was used, while the greater magnitude of the deflection of the current induced in the secondary measuring

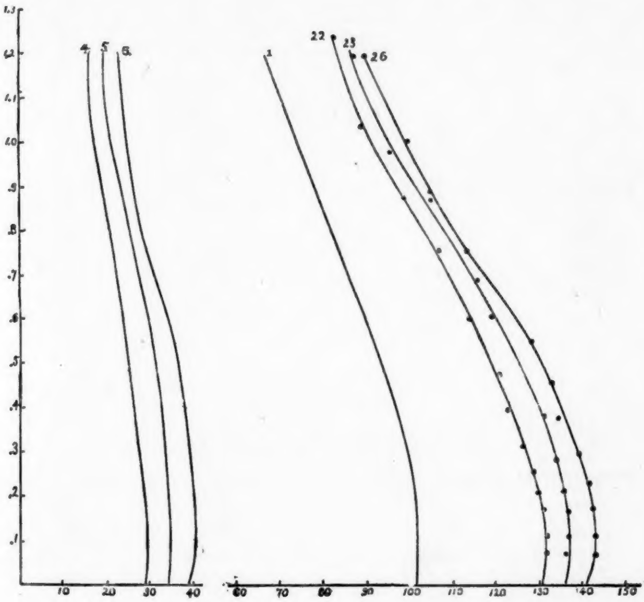


FIG. 3.

circuit allowed more satisfactory readings to be made than if the line current were smaller.

A corresponding series of measurements with a diaphragm of ferrotype iron, No. 31, B. W. G., 0.010 in. in thickness, gave the results found in Table VIII. and shown in Curve 31, Figure 2. Curve 2, Figure 2, is constructed with abscissas equal to the difference of the corresponding abscissas of Curves 31 and 1, and shows for various strengths of field the increase of the induced current due to the presence of the diaphragm, an interesting illustration of the action to which Du Moncel ascribed the chief efficacy of the diaphragm.

In order to study the effect of the thickness of the diaphragm, further measurements were made, using sheet iron diaphragms Nos. 21, 22, 23, 26, B. W. G., whose thickness was 0.032 in., 0.027 in., 0.024 in., and 0.018 in., respectively. The results of these measurements will be found in Tables IX. to XII. inclusive, and from them the Curves 21, Figure 2, and 22, 23, 26, Figure 3, were constructed. The numbers attached to the curves indicate the gage of the diaphragm. The curves numbered 3, 4, 5, 6, respectively, are constructed to show the effect due to the addition of the diaphragm of thickness indicated by the gage number, as already explained in the case of Curve 2, Figure 2.

TABLE VII.

No Diaphragm.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	101.5	.554	90.7
.070	101.8	.727	84.3
.167	101.2	.933	77.6
.244	101.0	1.043	71.8
.348	97.8	1.192	67.7
.445	95.2		

TABLE VIII.

Diaphragm, Ferrotype Iron, No. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	123.0	.488	110.9
.072	124.4	.625	101.7
.112	123.4	.754	93.2
.176	123.0	.897	84.0
.259	120.5	1.072	77.9
.327	118.7	1.235	72.0
.402	115.4		

TABLE IX.

Diaphragm, Sheet Iron, No. 21.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	131.0	.437	121.7
.073	130.2	.521	118.4
.107	130.0	.649	111.3
.167	129.7	.754	108.5
.207	129.2	.933	100.2
.257	128.0	1.076	92.2
.356	125.4	1.280	81.4

TABLE X.

DIAPHRAGM, SHEET IRON, No. 22.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	130.8	.394	122.2
.073	131.4	.475	120.2
.112	131.6	.601	113.9
.169	130.2	.754	106.4
.204	129.2	.875	98.4
.255	128.2	1.039	88.7
.313	126.0	1.235	82.7

TABLE XI.

DIAPHRAGM, SHEET IRON, No. 23.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	136.0	.488	128.4
.068	136.0	.603	118.4
.107	136.7	.690	115.5
.167	136.4	.869	104.9
.211	135.7	.979	95.4
.281	133.9	1.196	87.2
.380	130.9		

TABLE XII.

DIAPHRAGM, SHEET IRON, No. 26.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	140.9	.454	132.2
.068	142.7	.543	128.0
.112	142.4	.625	124.7
.175	142.0	.754	113.0
.229	141.4	.885	104.4
.298	138.7	1.004	99.2
.376	134.0	1.196	89.2

Several series of measurements were made with currents of widely different strengths, and with the thinnest and the thickest of the diaphragms used in these experiments, in order to ascertain whether the induced current in the measuring coil was proportional to the inducing line current, and since this was found to be sensibly the case, the strength of six milliamperes was adopted, as already stated.

Considerable trouble was experienced in obtaining satisfactory consecutive readings of the deflections, on account of the close proximity of the laboratory to the streets, rendered especially disturbing by the presence of the electric railway. The difficulty was avoided as far as

possible by working at night. In order to indicate the character of our results so far as the deflections of the ballistic galvanometer are concerned, the following values (Table XIII.) are given, from which the deflections in Table XII. are derived.

TABLE XIII.

Deflections.			Mean.	Half-deflections.
A	B	C		
281	283	281	281.7	140.9
285	286	285	285.3	142.7
285	284	285	284.7	142.4
284	284	284	284.0	142.0
283	283	282	282.7	141.4
277	278	277	277.3	138.7
269	268	267	268.0	134.0
263	265	265	264.3	132.2
256	257	255	256.0	128.0
249	250	249	249.3	124.7
226	225	227	226.0	113.0
210	208	208	208.7	104.4
199	199	197	198.3	99.2
178	178	179	178.3	89.2

It will be seen from inspection of any one of the various curves last referred to, that as the strength of the field increases, the induced current increases, and then gradually diminishes. This would of course be anticipated, as the increased magnetization of both the core and the diaphragm increases the strength of field in which the latter moves, and at the same time diminishes the susceptibility of both masses of metal to magnetization. The effect of the former predominates slightly at first, but is overpowered by the latter cause when the magnetization is increased. The Curves 2, 3, 4, 5, 6, show that the addition of the diaphragm causes a greater increase of the induced current at low than at high magnetizations of the core, as would naturally be anticipated.

Curves 21 and 22 are so nearly alike that they have been placed in separate figures to avoid confusion. It would seem from this coincidence that above No. 22 an increased thickness of diaphragm causes little effect.

A comparison of the curves will show that, with the exception of Curve 31, for which the diaphragm was of ferrotype iron, the value of the maximum induced current is greater according as the diaphragm is thinner; and also that the strength of field corresponding to this maximum current is likewise greater the thinner the diaphragm.

The following approximate values were found from constructions of the curves on a large scale.

For No.	26,	Maximum	Current =	142,	Field =	.18
" "	23,	"	"	137	"	.13
" "	22,	"	"	132	"	.10
" "	21,	"	"	131	"	.06

It also appears that with the thinner diaphragms the decrease of the induced current with increase of field, after the maximum value of the current is reached, is more rapid than with the thicker ones. Moreover, the deviation of the latter portion of the curve from a straight line is greater in the case of the thinner diaphragms.

The greater value of the maximum induced current with the thin than with the thick diaphragm would naturally be ascribed to the less stiffness of the former, and its consequent greater motion when a current passes through the line, although its smaller mass and greater ease of saturation must in a measure counterbalance this effect. The quicker approach of the thin diaphragm towards saturation will explain the more rapid falling off of the current with it, and also the less uniform rate of this change as the field increases. Curves 3, 4, 5, 6, showing the effect of the diaphragm, still further illustrate these facts.

It should be observed that the results which we have described do not necessarily show the varying acoustic effect of the receiver, since the amplitude of the motion of the diaphragm rather than the simple amount of the change of strength of the magnet determines the magnitude of the resulting air-waves, — at least according to the view commonly held. We hope to return to the study of this part of the problem, which is rendered somewhat difficult on account of the very small motion of the diaphragm.

Rogers Laboratory of Physics,
October, 1890.

XVII.

ON THE COMPARISON OF SOME ELECTRICAL CONDENSERS.

By Charles Nutt.

Presented November 12, 1890.

This article contains a comparative examination of some of the dielectrics most commonly used in condensers of large capacity.

Paraffine paper condensers are by far the cheapest, and for this reason it is desirable to know how good a condenser can be made using this substance as a dielectric. Certainly very great differences exist in paraffine paper condensers, and these differences are often due to the varying qualities of paper and paraffine used.

There are several kinds of so-called "paraffine papers" in the market, varying in thickness from tissue to heavy manilla. On account of small holes in it, two sheets of the tissue paper must be used between consecutive sheets of tinfoil.

One condenser made of this white tissue "paraffine paper," of about 2.5 microfarads' capacity, lost its entire charge in less than ten minutes. Its electrical resistance was less than a megohm. To be sure that the fault was not due to a few bad sheets, I tested the whole condenser by sections, all of which "leaked" badly. Other condensers made of this paper and of the similar brown tissue "paraffine paper" were as bad; some were worse.

Another condenser was very carefully made of the best quality of commercial paraffine paper, — a strong white rag paper of good texture, probably often used in condensers. Its capacity, as measured by discharging through the galvanometer immediately after charge, was 0.308 mfd. Its *resistance*, measured by an ordinary Wheatstone's bridge, was only 740 ohms! After loosening the clamps, the resistance fell to 250 ohms. When tested by sections, the insulation of the paper was shown to be uniformly poor. The presence of one sheet of this paper in a condenser would be enough to spoil it.

My experience seems to show that commercial "paraffine paper" is not fit for making condensers.

In preparing paraffine paper for myself, it was necessary first to decide upon the best kind of paper. I made a preliminary test, on

small condensers, of ten sheets each, to find the comparative insulation of various kinds of paper. I put the condenser to be tested under pressure, and connected it in circuit with a battery of four gravity Daniell's cells and a mirror galvanometer. The throw of the needle was disregarded, and the permanent deflection due to the current through the galvanometer and condenser was read.

Papers.	Deflections.
Pulp (news)	1.0
Book, glazed,	0.3
Bond, glazed,	2.05
Bond, unglazed, No. 18	1.95
Bond, unglazed, No. 21	1.30
Tissue, brown commercial paraffine	1.20

This test showed that the cheaper kinds of paper were better than the bond and that the commercial paraffine was no better than ordinary clean paper.

A more careful experiment was made to see which of the three chief kinds of paper gave the best insulation. Condensers were made of pulp, pure rag, pure linen, bond (mostly linen), and of Ravelstone writing paper (rag and linen). Each contained ten sheets (21.5 × 34.5 cm.) with tinfoil (12.6 × 30 cm.). Four gravity cells were used. The galvanometer was much more sensitive than the one used in the experiments given above.

Papers.	Deflections.
Pure linen (mean)	43.7
" " (several hours later)	59.0
Rag	6.0
Ravelstone writing	11.25
Pulp (news)	4.6
Manilla	17.5 (?)
Bond	58.0

This last deflection gradually increased till it was "off scale."

Three days later, with the same galvanometer and condensers, but with fresh gravity cells, an even more conclusive test was made. The condenser made of ten sheets of the commercial paraffine paper, used in the second condenser described above, gave a violent deflection "off scale."

Papers.	Deflections.
Bond	81.0 *
Pure linen	50.5 †
Ravelstone writing	21.0 ‡
Rag	11.8
Pulp	3.6

* Then the deflection slowly crept "off scale."

† The deflection crept from 22 to this point, where it was still increasing.

‡ This deflection crept from 10 upward in a few minutes.

The rag and the pulp papers show no disposition to change in resistance while the current is passing, and they give decidedly the best insulation. The bond and the linen papers seem to have constantly changing resistances. The newspaper cannot be obtained free from holes and bits of metal. The rag paper, on the other hand, is of good texture, and admirably suited for our purpose.

The galvanometer used in the above tests is a form of ballistic galvanometer, devised by Professor B. O. Peirce of Harvard College. The coils have a resistance of 2764 ohms. The period of the needle is 53 seconds.

A deflection of one scale division (equal to a deflection of 10 millimeters with a scale distance of 2.8 meters) indicates a current of $8. \times 10^{-9}$ amperes. With four gravity cells, one division indicates the presence in the circuit of 500 megohms. The resistance of the paper may therefore be expressed in megohms.

Construction of Condensers.

The paraffine was taken from 15 lb. cakes. Experience showed that, while dipping the paper, care must be taken to keep out dust and dirt, especially coal-dust, and to prevent the paraffine from getting hot enough to smoke. Each sheet was examined before and after dipping for specks of dust and metal and for holes. Each was dipped, allowed to soak, and then cooled by itself.

The condensers are numbered for convenience, and briefly described.

Condenser No. 1 was made of sheets of bond paper dipped in the paraffine, with sheets of tinfoil between them. It was tested for leakage during the process of building and after it was clamped. The clamps in this and the other condensers to be described were strong oak boards of suitable size, bolted together so as to get a large and evenly exerted pressure on the condenser. The terminals of tinfoil at each end were wrapped about a thin strip of copper, from which a wire passed to the outside to make connections, and were held by a strip of board screwed to the lower clamp. These clamps, etc. were carefully insulated from the condenser. All of the condensers were built on a similar plan, — parallel plate condensers with half the tinfoil connected at one end, the alternate sheets making the other half at the other end.

Dimensions of No. 1.

Sheets of paper	80
Thickness of condenser	1.14 cm.
" of tinfoil	.05 "

Thickness of one sheet tinfoil	.00066 cm.
" of paper sheet	.014 "
Area of tinfoil (12.7 × 30)	381 sq. cm.
Capacity calculated for an equal air condenser by Ayrton's formula	.1827 mfd.
Capacity found by comparison with No. 72 (Elliott Bros.) standard microfarad condenser	.417 mfd.
Specific inductive capacity	2.28

Condenser No. 2 was made exactly like No. 1, except that it had 106 sheets of paper.

Condenser No. 3 was made of 104 sheets of paraffined rag paper, of the same size as the sheets in No. 1.

Condenser No. 4 was made of pulp paper similar to that used by the daily newspapers. It is tedious to make a condenser of this, on account of "leaks" caused by small holes and bits of metal. No. 4 has 72 sheets of the same size as those in No. 1.

Experiments with these three kinds of paraffine paper condensers confirmed the results of the paper tests. No. 3 is by far the best condenser. I concluded, therefore, to use the rag paper in the larger condensers.

Nos. 5, 6, 7, and 8 were made of rag paper similar to that of No. 3, and of the same lot of paraffine.

Dimensions of Nos. 5 to 8.

Effective area of tinfoil 12.6 × 35 cm.	441 sq. cm.
Taking the specific inductive capacity as found, 2.28, we should require 67,437 sq. cm. of tinfoil for one microfarad capacity, or	153 sheets.

Condensers Nos. 5 and 6 required 154 sheets each to equal the capacity of the standard microfarad; No. 7 required 72 sheets to equal 0.5 mfd.; No. 8, intended for a tenth microfarad, contained 16 sheets.

Condensers Nos. 14, 15, 16, and 17 were made of the same lot of paper used in No. 5, but of harder paraffine. The melting point was determined at 51.5–52° C. No. 14 had 76 sheets; No. 15, 78 sheets; No. 16, 138 sheets; and No. 17, 16 sheets.

Condenser "G," also of paraffine paper, is an old instrument, made in the Jefferson Laboratory, of bond paper. It occupies a large uncovered box, and is held in place by paraffine, which completely surrounds and covers it.

Condenser No. 18, also of paraffine paper, was similarly protected by paraffine in a covered box.

I made a condenser of 12 sheets of bond paper soaked in boiled linseed oil. Its capacity appeared to be large, but it had a resistance

of only 15,000 ohms, and an electromotive force of its own large enough to deflect the galvanometer "off scale"! By charging No. 72 with this electromotive force, I found it to be $\frac{1}{14}$ volt. Of course such an instrument is useless as a condenser.

Condenser No. 9 was made of sheets of hard rubber carefully cleaned and laid up. Paraffine paper was used to insulate the condenser itself.

Dimensions of No. 9.

Mean effective area of tinfoil (12.6 × 24 cm.)	302.4	sq.cm.
Number of sheets	179	
Area of both surfaces of one set of tinfoil sheets . . .	44,754	sq.cm.
Mean thickness of condenser	4.17	cm.
" " tinfoil sheets	.098	"
" " rubber "	4.072	"
" " single rubber sheet	.027	"
Calculated capacity of equal air condenser	.165	mfd.
Mean observed capacity	.389	"
Specific inductive capacity	2.35	

Gordon gives as a mean value for the specific inductive capacity of ebonite 2.28, though some of his specimens yielded the value 2.31; Schiller gives 2.76; Wüllner gives 2.56.

Condenser No. 10 was made of about 80 sheets of thin naked mica. The margin around the tinfoil was only about a centimeter.

Condenser No. 11 was made of 32 mica sheets (15.4 × 20.5 cm.), coated, for insulation, with pure shellac applied with a small brush.

Condenser No. 12 was made of 40 sheets of the same lot of mica used in No. 11, coated, for insulation, with paraffine.

Condenser No. 13 was made of 20 sheets of this same lot of mica, coated, for insulation, by dipping into a dilute solution of the shellac, and dried a week before they were used.

Condenser No. 72* is a mica condenser made by Elliott Brothers, London. Paraffine is used for insulation.

With these twenty condensers I have made a large number of observations, some of which will be found in the following tables. The first table shows the degree of insulation attained. The condenser was charged, then immediately discharged, and the reading recorded in the second column. It was then charged again, and disconnected for the time noted in the first column. The third column gives the throw of the needle at discharge, and the fourth the apparent percentage of loss.

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* See these Proceedings, vol. iv. p. 145, "On the Charging of Condensers by Galvanic Batteries," by B. O. Peirce and R. W. Willson.

Condensers Nos. 1 and 2.

Minutes charged.	Throw of full Charge.	Throw at Discharge.	Loss Per Cent.
13.5	69.5	66.5	5.0
21.5	63.5	48.5	23.6
31.0	58.0	43.1	25.0
52.5	62.0	43.0	33.0
160.0	63.5	32.5	50.0
218.0	70.0	*29.5	58.0
2843.0	69.5	4.5	93.0

Condenser No. 3.

31.5	39.5	39.5	0.0
57.5	39.5	39.5 (?)	0.0
164.0	37.5	33.3	25.0
265.0	34.5	*29.1	35.0
1400.0	38.53	20.2	45.4
2806.0	39.5	2.5 (?)	93.0
3877.0	32.3	7.5	76.7
5896.0	32.2	6.2	80.0
14400.0	32.0	1.0 (?)	97.0

Condenser No. 4.

13.5	21.0	17.0	20.0
26.5	22.5	20.0	15.5
40.0	23.0	16.0	33.0
63.0	22.0	14.3	25.0
158.0	20.0	15.5	22.5
2635.0	22.0	7.5	65.0
4866.0	22.0	4.5	80.0

Condenser No. 5.

69.5	60.0	*47.5	20.0
5894.0	58.5	4.5	92.0

Condenser No. 6.

71.0	60.0	50.0	16.6
5894.0	58.0	3.2	93.0
14400.0	60.0	1.0	98.0

Condenser No. 7.

76.0	29.3	23.8	18.0

Condensers Nos. 14 and 15.

2.0	63.5	62.0	2.0
3.5	63.0	62.0	2.0
3846.0	61.0	41.0 (?)	40.0
5858.0	57.5	47.6	17.4
8900.0	56.0	39.0	30.0

Condensers Nos. 16 and 17.

Minutes charged.	Throw of full charge.	Throw at Discharge.	Loss Per Cent.
2880.0	54.0	49.0	9.0
14400.0	57.0 (?)	11.5	80.0

Condenser "G."

2.0	47.5	*42.2	10.0
120.0	47.5	21.3	59.0
199.0	46.5	30.5	35.0

Condenser No. 9.

3.5	24.5	*23.2	5.0
246.0	25.5	23.0	9.8
3877.0	22.0	19.5	11.4
6166.0	20.7	14.5	30.0
11168.0	21.5	13.2	35.0

Condenser No. 10.

3.0	47.5	43.5 (?)	8.0
6.0	47.5	29.7	30.0
3877.0	47.5	0.0	100 0
5896.0	47.5	0.0	100.0

Condenser No. 11.

5.0†	9.0	*7.5	15.0
11.0	18.0	15.5	14.0
4233.0‡	30.0	1.0	97.0
8760.0	17.7	3.5	80.0

Condenser No. 12.

7140.0	9.5	1.5	85.0
8760.0	7.5	2.6	66.0

Condenser No. 13.

4245.0	13.5	0.7	95.0

Condenser No. 72.

27.0	58.3	49.8	17.0
1190.0	65.5	*42.0	20.0
3854.0	56.0 (?)	47.0	16.0
5760.0	60.0	*36.0	40.0
5906.0	53.5	40.0	25.2

† Before clamping. ‡ Before shellac was dry.

In these and all the remaining experiments the period of the galvanometer was 45.1 seconds. Unless otherwise stated, the measurements were taken by *discharging* through the galvanometer. Measurements marked with a star (*) were taken by *charging* the condenser through the galvanometer.

The following table of capacities was determined by comparing the condensers with Elliot Brothers' standard microfarad No. 72 by the throws of the needle of a ballistic galvanometer.

TABLE OF CAPACITIES.

(Mean Values.)

Condensers.	Microfarads.	Condensers.	Microfarads.
1	.417	10	1.09
2	.636	11	.352
1 and 2	1.06	12	.192
3	.597	13	.158
4	.368	14 and 15	1.04
5	1.05	16 and 17	1.06–1.11
6	1.08	16	.945
7	.506	17	.115
8	.109	72	1.00
9	.389	G	2.78

None of these condensers has an electromotive force of its own.

With a poor condenser, the value of the throw obtained by charging through the galvanometer differs widely from that obtained by discharging. With four typical condensers, Nos. 9, 10, and 14 and 15, I compared the two throws. The time of charge was 0.2 sec. In the first column is given the throw produced by the charge. As soon as the needle was brought to rest, the condenser was discharged through the same galvanometer, and the throw noted in the second column. The per cent loss and the intervening time occupy the third and fourth columns respectively.

CONDENSER No. 9.

Charge.	Discharge.	Loss Per Cent.	Time in Minutes.
25.0	23.5	6.0	2.0
24.5	23.2	6.0	3.5
25.0	24.0	4.0	2.0
27.5	27.2	1.0	2.0
28.0†	28.1	0.5‡	2.0

† Left "soaking" to charge. ‡ Apparent gain.

CONDENSER NO. 10.

Charge.	Discharge.	Loss Per Cent.	Time in Minutes.
27.3	23.0	16.0	3.0

CONDENSERS NOS. 14 AND 15.

63.5	62.0	2.3	2.0
62.3	61.5	1.1	2.0
62.8	62.5	0.4	1.5
63.7	62.5	2.3	2.5
63.0	62.0	1.3	2.5

When as short a time as 0.002 sec. was tried in charging Nos. 14 and 15, the discharge exceeded the charge, but the results were too irregular to warrant any definite conclusions.

The first column of the following table represents the full charge, the second column the first residual discharge, the third the following residual discharges after the intervals denoted in the fourth column.

CONDENSERS NOS. 1 AND 2.

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
69.0 [17.5†]	4.0	11.7‡	1.0
70.0	15.0	....	2.0
....	....	6.5	2.0
....	....	4.0	2.0

CONDENSER NO. 3.

38.8	0.8	....	2.0
38.0	0.8	....	2.0
38.9	1.1	....	2.0
32.2	7.2	....	1.0

CONDENSER NO. 5.

43.0	9.0	....	3.5
....	....	2.1	2.5
....	....	1.8	3.5
....	....	2.2	6.5
*67.3	13.0	....	2.8
....	....	3.5	2.5
....	....	2.1	2.0
....	....	3.0	2.0
58.5	10.8	....	2.0

† After 1090 minutes' insulation.

‡ Equals sum of residual discharges the next 20 minutes at short intervals.

CONDENSER No. 6.

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
*60.0	9.0	....	2.0
*58.0	9.5	....	2.0
*72.0	12.5	....	....
44.0	9.0	....	3.5
....	....	2.1	2.5
....	....	1.8	3.5
....	....	2.2	6.5
56.5	10.0	....	2.0

CONDENSER No 9.

14.5	0.6	....	2.0
20.7	1.2	....	2.0
*34.5	8.5	....	1.0
....	....	3.0	2.0
....	....	1.3	2.0
....	....	1.1	2.0
....	....	1.0	3.0
....	....	1.3	3.0
....	....	0.3	2.0
47.5	4.0	....	3.0

CONDENSER No. 10.

59.3	4.0	....	2.0
67.5	8.1	....	4.0
69.0	7.0	....	1.5
....	....	3.5	2.0
....	....	1.7	2.0
....	....	1.5	2.0
....	....	2.0	2.0
....	....	1.5	2.0

CONDENSER No. 11.

18.0	2.2	....	1.0
....	....	1.2	1.0
15.5	1.5	....	1.0

CONDENSER No. 12.

9.7	1.7	....	1.5
9.2	1.5	....	1.5

CONDENSERS NOS. 14 AND 15.

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
47.6	8.7	....	4.0
....	....	2.5	2.0
....	....	1.1	3.0
57.5	9.8	....	2.0
39.0†	7.7	....	2.0

CONDENSERS NOS. 16 AND 17.

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
*64.5	12.5	....	2.0
*49.0	13.4	....	2.0
....	....	5.0	3.0
....	....	3.2	2.0

CONDENSER NO. 72.

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
53.5	1.5	....	1.0
*65.5	3.1	....	2.0
‡60.0	7.5	....	2.0
....	....	2.5	2.0
....	....	1.5	2.0
....	....	1.0	2.0
....	....	0.8	2.0
....	....	1.0	3.0
....	....	0.8	2.0
....	....	0.5	2.5
....	....	0.6	1.5
....	....	0.6	2.0
....	....	0.3	2.0
....	....	0.3	2.0
....	....	0.3	2.0
....	....	0.1	2.0
....	....	0.1	2.0
....	....	0.1	2.0
....	....	1.2	6.0
....	....	1.5	22.0
....	....	3.0	28.0

CONDENSER "G."

Full Charge.	First Residual.	Following Residuals.	Time in Minutes.
*49.0	26.0	....	1.5
....	....	2.4	3.0
*47.5	26.2	....	2.0
*43.5	29.5	....	3.0
....	....	3.5	2.0
....	....	1.0	2.0
....	....	1.0	1.0
....	....	0.5	2.0
47.5	12.5	....	2.0
....	....	5.3	2.0

† After long insulation. ‡ After long insulation 36 at discharge.

The time of charging was about 0.2 sec. The time was varied, but the results were not materially changed. I could not find a time of charging that would make the residue disappear. Of course the residue, as well as the charge itself, varies with the time of charging.

The following tables show the variations, with time of charging varying from 0.001 sec. to 30 sec., of the capacity of each condenser. The charging in short times was accomplished by means of the pendulum apparatus described in the Proceedings of the Academy, Vol. XXIV. p. 148. For longer times, a key was used. The measurement was made on discharging immediately after charging. All these measurements have been plotted, using the time in seconds for abscissas and the galvanometer deflections as ordinates. The curves are nearly parallel, and close to the axis of Y at first, but change rapidly, and in a good condenser become nearly parallel to the axis of X in a few seconds. The results give the means of four to ten observations. Where there is as much as two per cent disagreement in the observations, the mean is marked with a question mark. The time curve of a condenser is one of the best tests of its goodness. The capacities of leaky condensers vary greatly with the time.

Condenser No. 1.

Time in Seconds.	Throws.	Time in Seconds.	Throws.
.001	48.8	2.0	59.2
.012	51.0	3.0	60.0
.055	52.7	5.0	60.1
.098	54.1	10.0	61.1
.203	55.6	15.0	61.3
.295	56.1	30.0	61.8
1.0	58.4		

Condenser No. 2.

.001	40.0	3.0	45.4
.035	40.6	4.0	45.6
.125	41.6	5.0	46.0
.192	42.0	10.0	46.2
.209	42.2	15.0	46.3 (?)
.310	42.1	20.0	46.5
1.0	43.8	30.0	46.5 (?)
2.0	44.3		

CONDENSER No. 3.

Time in Seconds.	Throws.	Time in Seconds.	Throws.
.001	49.1	2.0	53.0
.011	50.0	3.0	53.8
.051	50.5	4.0	54.4
.100	51.1	5.0	55.2 (?)
.218	51.4	10.0	56.0
.326	52.0	30.0	56.6
1.0	52.3		

CONDENSER No. 4.

.001	30.0	1.0	33.0
.009	30.9	3.0	33.3
.038	31.3	5.0	34.7
.096	31.9	10.0	35.1
.210	32.5	30.0	35.3
.326	32.7		

CONDENSER No. 5.

.001	33.8	1.0	38.9
.013	34.8	2.0	40.0
.030	35.6	3.0	40.5
.061	36.4	4.0	40.9
.091	36.8	5.0	41.0
.158	37.4	10.0	41.5
.314	38.5	15.0	41.7
.326	38.4	30.0	41.9

CONDENSER No. 6.

.001	36.6	2.0	40.1
.028	38.2	5.0	41.0
.040	38.6	15.0	41.5
.301	39.6	30.0	42.4
1.0	39.8		

CONDENSER No. 7.

1.0	47.0	5.0	48.7
2.0	48.4	10.0	48.9
3.0	48.4	30.0	49.5
4.0	48.6		

CONDENSER No. 9.

Time in Seconds.	Throws.	Time in Seconds.	Throws.
.001	41.8 . . . 32.0	3.0	42.7
.022	41.8	5.0	43.1
.097	42.3	10.0	43.0
.192	42.8 . . . 33.0	15.0	43.0 . . . 33.6(?)
1.0	42.8	30.0	43.0 . . . 33.0
2.0	42.8		

CONDENSER No. 10.

.001	39.0	2.0	42.6
.005	39.5	3.0	44.0
.031	40.1	5.0	44.6
.150	40.5	10.0	45.2
.190	40.6	15.0	46.0
.300	40.9	20.0	46.7
1.0	41.3	30.0	46.6

CONDENSER No. 11.

.001	35.8	3.0	36.3
.120	36.0	4.0	36.3
.256	36.3	5.0	36.4
1.0	36.3	10.0	36.4
2.0	36.3	15.0	36.4

CONDENSER No. 12.

.001	12.5	4.0	12.57
.187	12.4	5.0	12.7
.315	12.5	10.0	12.7
1.0	12.5	15.0	12.7
2.0	12.55	30.0	12.7
3.0	12.5		

CONDENSERS NOS. 14 AND 15.

.001	40.0	0.270	40.8
.030	40.0	1.0	40.8
.0304	40.2	5.0	41.2
.051	40.0 (?)	10.0	41.2 (?)
.096	40.2	15.0	41.4
.102	40.0	20.0	41.4
.143	40.2		

CONDENSER No. 18.

.001	50.0	3.0	85.8
.122	68.5	4.0	87.5
.314	74.0	5.0	89.0
1.0	80.8	10.0	90.8
2.0	85.4	30.0	92.6

Condenser No. 72.

Time in Seconds.	Throws.	Time in Seconds.	Throws.
.002	67.84	3.0	71.0
.025	68.30	4.0	71.0
.226	69.30	5.0	71.3
.340	70.48	10.0	71.15
1.0	70.80	15.0	71.6
2.0	71.0	30.0	71.2

These results indicate that, while hard rubber is probably the best dielectric for a standard microfarad, the paraffine paper condensers, Nos. 3, 14, and 15, and the standard, No. 72, are extremely well insulated and vary very little with time of charging. The experiments prove that a paraffine paper condenser can be made that compares favorably with a good mica condenser.

The mica condensers that I made "leaked" more than No. 72, because, I suspect, of the narrowness of the margin of mica around the tinfoil. The paraffine paper condensers gave larger residual discharges than either the mica or hard rubber condensers. That was their worst fault.

A paraffine paper condenser is necessarily much larger and heavier than a mica condenser of the same capacity, but far less expensive. In the tables below I have estimated the cost of the materials in microfarad condensers, using the three sorts of dielectrics that I found best adapted for making condensers.

Hard rubber	$30.00
Tinfoil	1.50
Clamps	.75
	$32.25

Mica	$10.00
Tinfoil	.50
Shellac	.25
Clamps	.75
	$11.50

Paraffine	$.75
Paper	.50
Tinfoil	.75
Clamps	.75
	$2.75

Jefferson Physical Laboratory.
June, 1890.

XVIII.

NOTE ON THE PRESSURE COEFFICIENT OF THE VOLTAIC CELL.

By Carl Barus.

Presented January 14, 1891.

Subjecting cells of Zn/Pt and of Zn/Cu, in dilute sulphuric acid and Daniell's cells, to pressures between 10 and 1800 atmospheres, at temperatures between 15° and 300°, I obtained certain results bearing on polarization, the temperature coefficient, and the pressure coefficient of the galvanic couple. For the purposes of the present note I need only give the pressure coefficient, κ, of the Daniell's cell at 15°, $\kappa = -5/10^6$ (volts per atmosphere), whereas the ordinary temperature coefficient is $-200/10^6$ (volts per degree).

The feature of these results, corroborated by my other data, is obvious: the pressure coefficient (volume contraction) and the temperature coefficient (volume expansion) have the same sign. Hence, quite apart from changes of volume, quite apart from what in a liquid corresponds to the mean free path of the molecules of a gas, the observed change of electromotive force is to be associated with the change of the stability, or the vibration status of the galvanic system as a whole. I infer from this, that the secret of the relation of the Volta contact to the Peltier contact, will probably fall into the possession of him who devises means for carrying a suitable galvanic cell, suitably compressed, through a large range of temperature (I mean fully into red heat). For it is thus possible to discriminate between the metallic contacts and the other contacts, by exposing any one or all of them in the thermal field.

An allied electrical result, indicating a specific effect of temperature even on the metallic molecule, I observed some time ago by compressing mercury and a solution of zinc sulphate. I deducted the isopiestic resistance decrement per unit of volume decrement, from the corresponding isothermal resistance decrement per unit of volume decrement, of the same substance. Thus I found that the purely thermal effect of rise of temperature (i. e. the effect apart from change

of volume) is an *increase* of electrical conductivity both for the metal and for the electrolyte. Conduction in metals and electrolytes thus takes place in ways essentially alike.

The present results lend themselves favorably to certain views on the possibility of an ion theory of magnetism which I have indicated elsewhere (Nature, Vol. XLI. p. 370, 1890); viz. that in a magnet the split up or the transfer of charges is directed along paths of closed helices, each of molecular diameter, consisting of right and left handed screw threads, with their ends joined and their axes in the direction of the lines of magnetic force. An advantage is gained in this way, since a definite relation of the magnetic quality to the molecular structure is implied. It may be stated generally, that in metals a definite degree of molecular break up corresponds to each temperature; and that electrical action (appearing either as static charge, current, or magnetism) is manifest, whenever the break up is suitably directed.

XIX.

SUPPLEMENTARY NOTE ON NORTH AMERICAN LABOULBENIACEÆ.

By Roland Thaxter.

Presented by W G Farlow, January 14, 1891.

In a previous note "On Some North American Species of Laboulbeniaceæ,"* the writer gave a short account of the family, at the same time enumerating the North American species then known, with the intention of illustrating them in a monograph, together with any subsequently discovered forms, as soon as practicable. The additions of a single season, however, have been so considerable, that it seems best to defer still longer a monograph which, if based on the data at present available, could not even approach completeness. A very limited opportunity for observation during the past summer, both as to time and as to locality, has served to more than double the number of forms previously reported; so that the family bids fair to become a numerous one in this country, where with the present additions its members already outnumber all the known exotic species. It seems, therefore, very desirable to obtain further information, if possible, especially concerning extra New England forms, before attemping a general work upon the subject.

Of the species described below, the very remarkable form which is called *Zodiomyces* is chiefly interesting, and forms a distinct departure from any of the known genera of the group. In *Cantharomyces* and perhaps in *Peyritschiella* an approach is made toward a compound type; but so high a development of this type as is found in the new genus was hardly to be looked for, and is suggestive of the many interesting possibilities of variation which further study of the family may bring to light.

Peyritschiella receives one additional species, which indicates that the genus is a well marked one, corresponding to the diagnosis previously

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* These Proceedings, *ante*, page 5.

given in all respects except for the absence of a single supra-basal cell, the receptacle in the present species becoming multicellular above the basal cell. Further material of *Cantharomyces*, although diligently sought for on Staphylinidæ, has not been obtained. The new genus *Hesperomyces* seems to present such important differences from its ally, *Stigmatomyces*, as to render necessary the separation of the two. The lateral development of its asci, as well as the lower insertion of its antheridial appendage, suggest its relationship to *Helminthophana*, as does its very large, thrice-constricted perithecium.

The additions to the genus *Laboulbenia*, which do not include several species descriptions of which are reserved until further material can be obtained, are, as usual, the most numerous, and conform strictly to its more simple type. The highly developed branching trichogyne, previously mentioned in connection with *L. elongata*, is present in a number of the species described, and in the younger stages at least the bottle-shaped antheridia, to which attention was called in my previous paper, are invariably present. From the latter the emission, singly, of spermatia has been repeatedly observed. The definite isolation of asci containing immature spores, an observation readily verified in *L. Nebriæ*, should also be mentioned as setting the ascomycetous nature of the group beyond further question. Other points of morphological interest have been noticed in connection with certain abnormal forms, in which the perithecium may be partly or wholly replaced by antheridial appendages, with or without the usual black base of insertion; while in a few cases, where fertilization had apparently not taken place, the initial cells which usually give rise to asci were observed to produce numerous long filaments growing out through the pore of the perithecium and filled with spermatia-like bodies.

As in the previous note, the term receptacle is used to designate the main body of the fungus, the side bearing the perithecium being spoken of as the *inner*, while that bearing the pseudoparaphyses is spoken of as the *outer*, where this distinction is possible. As a matter of convenience, the eight typical cells of the receptacle in *Laboulbenia* are numbered as follows: the basal (1); the supra-basal (2); the cell above 2 on the outer side (3); the cell above this (4); the cell formed by a partition across the upper inner angle of 4 is numbered (5); the cell above 2 on the inner side is numbered (6); while of the two remaining small cells which form the base of the perithecium the inner is numbered (7), the outer (8).

ZODIOMYCES nov. gen.

Main body of the fungus tapering to a narrow base of attachment, parenchymatously multicellular; the distal end cup-shaped, with a more or less well marked rim, within which arise directly from the central parenchyma numerous stalked perithecia and simple, septate sterile filaments. Perithecia asymmetrical; the apex bent to one side; appendaged; borne on simple, septate pedicels, having a rounded prominence just below the perithecium. Spores hyaline, fusiform, asymmetrically once-septate, involved in mucus.

ZODIOMYCES VORTICELLARIA nov. sp.

Livid with a central yellowish tinge, the base more or less suffused with dull purple above the almost black point of attachment. Perithecia numerous: at first terminal, then lateral by the subsequent outgrowth of the terminal cell of the simple, cylindrical, several-septate pedicels which bear them: strongly bent away from a pair of ear-like appendages placed close together near the summit which curve away from the almost symmetrical rounded apex of the perithecium. Two additional appendages, longer, more slender, slightly curved and tapering, arise from slight prominences on opposite sides of the perithecium, at a point about two thirds of the distance from the base to the apex. Sterile filaments arising among the perithecia; simple or rarely branched, cylindrical, septate, tapering slightly towards a rounded apex and extending some distance beyond the perithecia. Main body, or receptacle, trumpet-shaped; made up of very numerous small, squarish or slightly elongate cells, smaller towards the distal end and disposed in more or less regular transverse layers; the base of attachment composed of several small cells placed side by side and more or less deeply tinged with purple. The basal portion may or may not grow out laterally, on one or both sides, forming rounded processes of parenchymatous cells of variable size, which may be in contact with, though not attached to, the host. Spores slender, fusiform, hyaline, slightly granular, involved in mucus, asymmetrically once-septate, $45 \times 2.5\text{–}3\ \mu$. Perithecia $55 \times 15\text{–}18\ \mu$; ear-like appendages $15\text{–}30 \times 5\ \mu$; lateral appendages, maximum $50 \times 3\ \mu$; pedicels $35\text{–}50 \times 3.5\text{–}4\ \mu$. Sterile filaments (longer) $200 \times 3\text{–}4\ \mu$. Main body exclusive of perithecia and sterile filaments, largest observed $400 \times 185\ \mu$ at distal end; smaller specimens $225 \times 100\ \mu$.

On legs of *Hydrocombus lacustris.* Connecticut.

This extraordinary plant was found in a single locality near New Haven, and appears to be very rare, ten specimens only having been observed. In large individuals the number of perithecia may reach one hundred or more, in various stages of development. The trichogyne is simple, growing downwards from the apex of the immature perithecium; but no sign of any antheridial appendage was seen on the same pedicel, unless it is represented by the apical cell of the latter, or its outgrowth, which appears, however, to be developed after fertilization. It is also possible that the differentiation between the sexes has led to their complete separation, and the male may be represented by certain short-stalked bodies resembling very young perithecia. The point where the trichogyne emerges is not, as in *Laboulbenia*, the point which subsequently becomes the apex of the perithecium; but, as is probably the case also in *Cantharomyces* and perhaps other genera, becomes lateral as the latter develops. The two pairs of appendages are doubtless protective and appear after the perithecium has attained considerable size. The lateral outgrowths from the base of the main body, or receptacle, are singular productions, also doubtless protective, serving as cushions against sudden lateral bending.

HESPEROMYCES nov. gen.

Perithecium asymmetrical: thrice transversely constricted, with an abruptly conical, appendiculate apex: borne on two cells, one of which is prolonged downwards to form a pedicellate connection with the receptacle. Receptacle of three cells, one basal and two distal, from the outer of which arises the antheridial appendage; from the inner (as a bud) the stalked perithecium. Antheridial appendage simple, cylindrical, septate, with a single lateral row of tooth-like projections.

Hesperomyces virescens nov. sp.

Color wholly yellowish green. Perithecium very large: nearly straight on the inside, rounded externally; its three constrictions at nearly regular intervals; tapering slightly to the base and abruptly to the often slightly bent, sharp apex; the apex proper made up of two sharp more or less evenly apposed, nearly equal projections, enclosing the apical pore between them; while lower down in a plane at right angles to these are two more appendages placed laterally (the perithecium and antheridial appendage being considered antero-posterior) on opposite sides of the apex, finger-like, curved outwards and

often once-septate. External to the base of each of these finger-like appendages is a short projection. The outer basal cell of the perithecium is small, sub-triangular; the inner continued downwards beyond the outer into a rather broad pedicel connecting with the receptacle. Receptacle composed of three cells: the basal simple, with a small black base of attachment to the host, bearing distally two cells: the outer small, roundish, or polygonal; the inner larger, extending some distance obliquely downwards on the inner side of the basal cell, and forming the base of the pedicellate perithecial cell which occupies its whole upper face: the smaller outer cell gives rise to the antheridial appendage, which occupies only a portion of its upper face. Antheridial appendage slightly constricted at its base, which is wholly distinct from the pedicellate basal cell of the perithecium: subcylindrical, five-septate, each cell above the second giving rise to single (exceptionally two) curved, rather slender tooth-like projections, one terminal, the rest lateral and external, each (except the terminal one) separated by an oblique partition from the cell which bears it. Spores of the usual type, sometimes appearing more than once-septate, the smaller segment sometimes vacuolate and spherically distended at one point: $65 \times 6\ \mu$. Perithecium proper (without basal cells) $250–260 \times 66\ \mu$; longer apical appendages $40–45\ \mu$. Receptacle (proper) $75 \times 30\ \mu$. Antheridial appendage $75 \times 13\ \mu$. Total length to tip of perithecium $300–400\ \mu$; average $375\ \mu$.

On *Chilocorus bivulnerus*. California.

It is not without some reluctance that this form is separated generically from *Stigmatomyces*, to which it is most nearly allied, especially through its antheridial appendage, which is very similar to the form occurring in this genus. The genus is based chiefly upon the very peculiar appendiculate perithecium, and the different relative position of its antheridial appendage. Another important point of difference lies in the fact that, while in *Stigmatomyces* the asci arise by budding upwards from the base of the perithecium, in the present genus the ascogenic area is lateral, the asci budding downwards, outwards, and upwards from a portion of the wall of the perithecium opposite and below its lowest constriction, on the inner side. In its younger stages the receptacle is triangular, and the perithecium and antheridial appendage bud from its two upper angles obliquely outwards and upwards, the former on a slender base at first, which ultimately becomes vertical, continuing the main axis of the receptacle, while the antheridial appendage becomes sub-lateral in position. The trichogyne is simple and of large diameter.

I am indebted to the kindness of Mr. Coquillet for sending me two specimens of *Chilocorus* bearing this parasite upon the legs and ventral surface of the abdomen, on which it is conspicuous from its large size and contrasting color.

Peyritschiella minima nov. sp.

Hyaline or slightly yellowish. Perithecia large, tapering slightly to a blunt, 4-papillate, symmetrical apex. Paraphyses sometimes brownish, of two or three rounded joints: on the inner side, in sets of (typically) three each in a transverse row, surmounting prominent, slightly overlapping projections from three successive cells placed one above the other, the lowest being the third above the basal cell of the receptacle. On the outer side, above the sharp projection characteristic of the genus, and external to the base of the perithecium, are usually three more similar pseudoparaphyses. Receptacle short, stout, subtriangular, of twelve or more cells; the small basal cell being the only one which is single. Spores of usual type 37–40 × 4 μ. Perithecia 100 × 33 μ. Paraphyses, maximum 35 μ. Total length to tip of perithecium 190 μ; maximum 220 μ. Receptacle 90–110 × 50–58 μ.

On *Platynus cincticollis*. Connecticut.

A very distinct and minute species, hardly visible with a hand lens, growing singly on the extremities of its host. The peculiar sharp process, also present in *P. curvata*, does not project laterally beyond the receptacle, as in the last named species, and is therefore visible only when the receptacle is so placed that its inner side lies to the left. Single perithecia only were observed in the seven specimens which constitute the types, although more than one may be found to occur, as is very rarely the case in *P. curvata*. Without reference to other points of difference it is at once separable from *P. curvata* in having no single supra-basal cell, the receptacle becoming multicellular immediately above the basal cell; a circumstance which renders necessary a modification of the generic diagnosis previously given, in which the supra-basal cell is described as single.

Laboulbenia Casnoniæ nov. sp.

Evenly pale olivaceous. Perithecium rather long, with a black patch below the apex on the inner side: apex hyaline, slightly oblique outwards. Pseudoparaphyses hyaline, olivaceous near the base: the outer simple, nearly straight, slightly divergent: the inner consisting of a small basal cell from which arise several branches, which may in

turn be once branched, not attaining, however, more than half the length of the outer pseudoparaphysis: disk of insertion oblique. Receptacle moderate, cell (1) rather short subtriangular; cell (2) large; cells (3) and (6) about equal. Spores of usual type $35–40 \times 4\ \mu$. Perithecia $75 \times 30\ \mu$. Pseudoparaphyses: outer, maximum $170\ \mu$; inner $75\ \mu$. Total length to tip of perithecium $160\ \mu$; greatest width $35–40\ \mu$.

On *Casnonia Pennsylvanica.* Connecticut.

A very small species, not nearly allied to other forms, yet without marked individual characteristics beyond its uniform pale olivaceous tint, and the peculiarity of its pseudoparaphyses. Sixteen specimens examined from the tips of the elytra and abdomen of the host.

LABOULBENIA TRUNCATA nov. sp.

Dark olive-brown, sometimes nearly opaque. Perithecia large, the middle third expanded slightly just above the insertion of the pseudoparaphyses, otherwise subcylindrical; the dark truncate apex slightly oblique inwardly, usually as broad as the base, with large nearly hyaline lips about the pore. Pseudoparaphyses two: the outer straight, stout, dark brown at the base, unbranched, tapering to a slender hyaline apex: the inner short, slender, simple, hyaline, its base occupying less than a third of the horizontal black disk of insertion, which is situated about opposite the middle of the perithecium. Receptacle short, wedge-shaped: cell (1) triangular, its lower half nearly hyaline, its upper as dark as the basal portion of the outer pseudoparaphysis; cell (2) large, about as broad as long, separated from cell (6) by a long oblique partition extending nearly across the receptacle, and from cell (3) by a very short, nearly horizontal septum; cells (3) and (4) about equal: cell (6) very flat; cell (8) rather large, triangular; cell (7) almost obsolete. Spores of usual type $60 \times 4.5\ \mu$. Perithecia $90–100 \times 35–40\ \mu$. Pseudoparaphyses, outer $150\ \mu$. Total length to tip of perithecium $175–180\ \mu$. Greatest width $66\ \mu$.

On *Bembidium* sp. Connecticut.

A very small and singular species approaching *L. Nebriæ* in the type of its pseudoparaphyses, while its peculiar perithecium distinguishes it at once from other known species. Twelve specimens only were examined from the legs of an undetermined species of *Bembidium.*

Laboulbenia arcuata nov sp.

Usually strongly curved inwards, hyaline or slightly smoky, except for the perithecium. The latter very large, smoky black, nearly opaque, tapering slightly to a broad, rounded, less deeply colored apex, which is symmetrical or slightly oblique inwardly. Pseudoparaphyses two, hyaline or tinged with brown, projecting obliquely outwards, arising from two basal cells: the inner small, roundish; the outer several times as large and bearing the larger of the two pseudoparaphyses, both of which are one to three times branched above the supra-basal cell; disk of insertion oblique, about one fifth of the distance from the base to the tip of the perithecium. Cell (1) of the receptacle long and broad, usually curved; cell (2) somewhat shorter, divided from (6) by a very oblique partition, from (3) by a nearly horizontal one; cells (7) and (8) involved in the opaque color of the perithecium. Spores of usual type 65 × 4.5–5 μ. Perithecia 160–185 × 50–55 μ. Pseudoparaphyses, maximum 240 μ. Total length to tip of perithecium 300–350 μ; average 320 μ.

On *Harpalus Pennsylvanicus*. Connecticut.

A somewhat rare species, occurring on the legs of its host in small tufts, and readily seen even without a hand lens. It may be recognized by its usually very strong curvature and the association of a large opaque perithecium with a hyaline or only slightly smoky receptacle. Described from thirty-five mounted specimens.

Laboulbenia conferta nov. sp.

Hyaline or tinged with smoky brown, the base of the perithecium and the adjacent cells often dark brown. Perithecium short and broad; tapering rather suddenly towards the apex, which is black except about the hyaline pore, and slightly oblique outwardly. Pseudoparaphyses hyaline or brownish; the outer much the largest, its basal cell twice as large as that of the inner, and giving rise typically to three branches, themselves once or twice two- to three-branched above their basal cell; the inner similar but smaller; both the outer and inner varying to more simple forms: disk of insertion small, very slightly oblique, placed slightly above the base of the perithecium. Receptacle rather long: cells (1) and (2) about equal, cell (3) usually about twice as large as (4) and (5) together. Spores of usual type 50 × 16 μ. Perithecium 130 × 60 μ. Pseudoparaphyses, maximum 300 μ. Total length to tip of perithecium 300 μ; greatest breadth 70 μ.

On *Harpalus Pennsylvanicus.* Connecticut.

Occurs in usually single, crowded tufts on the legs of its host. It is a rare species, allied to *L. elegans,* from which it is at once distinguished by its pseudoparaphyses. Described from twenty-six mounted specimens.

Laboulbenia paupercula nov. sp.

Color brown to blackish or slightly olive. Perithecium rather broad; the apex hyaline about the pore, black on the inside. Pseudoparaphysis single; hyaline, slightly smoky near the base, simple or once dichotomously branched above the supra-basal cell: a usually short antheridial branch arises from the left side of the basal cell (the pseudoparaphyses being considered as placed anteriorly); disk of insertion oblique, about one quarter of the distance from the base to the apex of the perithecium. Cells (1) and (2) of the receptacle rather short: (2) separated from (3) and (6) by usually oblique septa: cell (5) usually wholly or partly free from the perithecium, or sometimes obsolete: spores of usual type $45 \times 4.5\ \mu$. Perithecia $100 \times 40\ \mu$. Pseudoparaphysis, maximum $350\ \mu$. Total length to tip of perithecium $160–222\ \mu$.

On *Platynus extensicollis* and a Carabid beetle (undetermined) found in dry fields. Connecticut.

A small and inconspicuous species, usually growing scattered on the thorax or elytra of its host. It is distinguished from all other described species by its anomalous single paraphysis. Described from twenty mounted specimens.

Laboulbenia scelophila nov. sp.

Color olive or smoky olive, cell (1) usually colorless. Perithecium large, subcylindrical, greenish olive, tapering somewhat abruptly to the rather small apex; which is hyaline about the pore, blackish on either side, and bent slightly towards the pseudoparaphyses. Pseudoparaphyses three, the outer and inner arising from two main basal cells, the basal cell of the third inserted like a wedge between them, and thus arising from the septum which divides them: all three pseudoparaphyses once to twice dichotomously branched and very strongly curved inwards so as usually to pass beyond and partly conceal the apex of the perithecium; disk of insertion horizontal, situated a little more than one third of the distance from the base to the apex of the perithecium. Receptacle short, tapering evenly to a slender base: cell (2) twice as long on the outer as on the inner side, separated from

cell (6) by a very oblique, almost vertical septum; from cell (3) by a short, horizontal septum: cell (6) twice as broad as long, its upper and lower septa parallel: cell (7) nearly obselete; cell (8) rather large, triangular. Spores of the usual type $50 \times 5\ \mu$. Perithecia $100–120 \times 40–50\ \mu$. Pseudoparaphyses, maximum $180\ \mu$. Total length to tip of perithecium $200–220\ \mu$: greatest width $55\ \mu$.

On *Platynus extensicollis.* Connecticut.

Occurs in small numbers always on the legs of its host, its most noticeable character being the curvature towards one another of the pseudoparaphyses and the apex of the perithecium. A rather rare species, described from thirty-two mounted specimens.

NOTE. — Types of all the species of Laboulbeniaceæ described by the writer are contained in Herb. R. Thaxter and Cryptogamic Herbarium, Harvard University.

XX.

ON CHANGE OF FORM AFFECTING A MAGNETIC FIELD.

By A. Emerson Dolbear.

Presented January 14, 1891.

Hitherto, the study of a magnetic field has been the study of the so-called lines of force radiating from the poles of magnets, either electro or permanent; and, so far as magnetism has been utilized in the arts, the changes in this external field have been brought about by the movements of an armature, having for its function to determine the direction and consequent density of the field. Such is the case in the instruments used in the telegraph, the telephone, in dynamos, and in motors. Sometimes, conducting wires are so mounted in the field that their movement gives rise to electric currents; which signifies that the energy producing the tension in the field is absorbed in some measure by the moving wires, and is transformed into an electric current. In each of these cases the magnet producing the field is stationary; that is, changes in the magnetic field produced by it are due to a motion external to the magnet itself, and may be that of an armature, of a moving wire, or of its own bodily change of position, — a kind which is comparable with what is called external motion in thermodynamics, to distinguish it from internal motions, or such as take place when the body changes its form. So far as I am aware, no study has been made of the effect of changing the form of a magnetic body on its field, or of the reaction upon itself of its magnetic condition due to a periodic change of form. Of course, it has been known for a long time that the form of the magnetic field depended upon the form of the magnet itself. For a straight bar magnet, this field is familiarly known by the arrangement of iron filings forming curved lines from each pole re-entering the opposite pole. When the iron is bent into a U-form, or horseshoe magnet, the field is mostly contracted to the space between the poles. These forms of magnets have been *permanent* ones for the purpose for which the magnet was made.

In the case of induction coils, whether of one form or another, the magnetic change produced by it has been and is due to the *electric* change produced upon it by an electric circuit provided with intermittent or alternating currents.

Within a few years, attention has been called to the nature of the external field, as being a part of what is now known as the magnetic circuit, which consists of these *rings* or closed circuits of lines of force, all originating in the iron part of the circuit, and for *conducting* which iron is by far the best. The poles of the magnet are simply the parts of the iron where the lines enter and leave, and they may be in any place. Usually, they are at the ends of the iron, but not necessarily so. Whenever iron is placed in the magnetic field, these lines crowd into it, as it is a much better conductor than the ether. When the iron is made into a ring form and then magnetized, there is no external polarity, and consequently no external field, provided that the iron has sufficient conducting cross section at every part.

The following experiments have been tried, to determine what effects, if any, are produced upon a magnetic field by changing the form of the magnet. It was thought, at first, that if a helix was coiled into a circle, and a current was present in it, changes in its form would produce corresponding changes in the magnetic field external to the coil, especially noticeable if a flexible iron ring was enclosed in the helix so as to condense the magnetic field. This was put to the test in the following manner.

I. A coil, similar to the one described above, but containing a solid ring of iron, about eight inches in diameter and an inch thick, had its coil put in circuit with a reflecting galvanometer of low resistance, and at such a distance from it that magnetic fields external to its circuit could not act upon it. Another coil made about a flexible ring of iron wire, was put in circuit with a battery so as to magnetize the ring strongly. Then, with one ring parallel to the other, the flexible one was made suddenly to assume an elliptical form. Each such change in form, from one ellipse to another at right angles to it, gave a deflection of the needle to the right or left, and uniformly for a given phase of change. It was also observed that the direction of the deflection was reversed when the flexible ring was turned the other side up.

II. The same flexible ring, used in the same way, but without the current through it, gave substantially the same results. Of course the ring was permanently magnetized, and the change might have been inferred.

III. As the same kind of motion, due to change of form, is taking place when a ring is vibrating at its harmonic rate, producing what we call sound vibrations, it was thought probable that a magnetized ring, having a coil of wire about it in connection with a telephone, would set up vibratory currents when it was struck; and this was found to be true, for when the coil containing the heavy iron core was put in circuit with a telephone in another room, the sound of the stroke and the pitch of the ring could plainly be heard. In the first case, the number of turns of wire was small, perhaps fifty or thereabouts. I therefore had two larger rings made, each about one foot in diameter and half an inch thick.

IV. One of these was wound with six or seven hundred turns of No. 32 wire. Before it was magnetized, it was connected with the telephone, and tested for its magnetic condition by striking. The ring could plainly be heard, which showed that it had some degree of magnetism.

V. Then about two hundred turns of coarse wire were wound upon it, and a strong current sent through it to magnetize it. After this magnetizing coil had been removed, the ring was again tested as in IV. The sound was very much louder. Indeed, the telephone could be held a foot from the ear and be heard.

VI. With the ring in V. still in circuit, the companion ring, without any wire upon it, was brought near it and struck. The sound was easily heard in the telephone circuit.

VII. This second ring was now magnetized in the same way as the first, when the magnetizing helix was removed, and experiment VI. repeated. The sound was *very* much louder.

VIII. The ring was now struck and moved away from the first ring by stages of an inch or two at a time. It was found possible to hear its pitch in the second circuit, when it was a yard or more away from it.

IX. As the pitch of the two rings was not quite the same, the higher one was loaded so as to bring them to unison. The sound was then louder and more persistent than before. This gave evidence that it was a case of sympathetic vibration, while the former were forced vibrations.

X. A common horseshoe permanent magnet, with legs about six inches long, had perhaps fifty ohms of No. 32 wire wound about the bend, and this was put in circuit with the telephone, and struck like a tuning fork. The sound in the telephone was remarkably loud, indeed too strong to be held comfortably at the ear.

XI. A coil of wire was now put about the middle of a piece of gas-pipe, which was without permanent magnetism. The piece of pipe was about 4 feet long and $\frac{5}{8}$ of an inch in diameter. This, when in connection with the telephone, was struck two or three times a second, with a piece of brass rod, and while being thus struck it was rotated from the magnetic meridian to a position at right angles to it. The difference in the loudness of the sound, between the position in the meridian and away from it, was very marked. It is therefore shown to be possible to determine the points of the compass with a telephone, a coil, and an iron rod.

XII. A second flexible ring was now made, about a foot in diameter, consisting of a bundle of soft iron wire, the ends being roughly braided and twisted together: the thickness of this was rather less than half an inch. This was covered by a rubber tape wound spirally round it, the better to secure stability of form and insulation. Then 4.6 ohms of No. 21 wire were wound about it its entire length, making probably 1,000 turns. It was then magnetized by a current from three secondary cells having six volts, giving a magnetizing current of about 1,300 ampere turns, leaving it a ring magnet. The terminals were then connected with the terminals of a reflecting galvanometer with a resistance of .67 ohm. Very slight changes in the form of the ring, either by pulling or pushing, gave decided movements to the needle, while larger amplitude gave 30 to 40 degrees' deflection.

XIII. It was noticed, also, that the direction of the current depended, not only upon the direction of the motion changing the form, but also upon the direction of the motion with reference to the normal shape of the ring. Thus, if the ring be a circle, and it be drawn into a horizontal ellipse, the current will move the galvanometer needle, say to the right. When it is brought back to the circular form, the current is reversed. If the motion be continued so as to produce a vertical ellipse, the current will be in the same direction as that produced at first by a motion exactly opposite in direction, so that for a complete cycle of vibratory changes four currents are generated, two direct and two reverse.

XIV. One of the iron rings before mentioned, a heavy one about eight inches in diameter and an inch and a half thick, having coarse wire wound upon it nearly covering the ring, was connected with the galvanometer as before, and the ring was struck by a brass rod. The needle instantly swung through a wide angle. Struck again, it moved as before, but not through so wide an angle, and a half-dozen blows

knocked nearly all the magnetism out of the ring. This was then detached from the galvanometer and magnetized as before, when it again gave the same large deflection it gave at first. The same conditions were tried with other rings, and in each case it was found that a vigorous stroke upon the ring magnet had the same destroying effect upon the magnetism as it is known to have upon magnets having external fields.

XV. The flexible ring was now put in circuit again, and vigorously jerked with the hands. A very few such movements served to destroy nearly all the magnetism present, requiring the remagnetization of the ring.

As flexible iron rings such as I wanted were not easy to make, I procured some steel wire rope of the right size, and the ends were welded for me through the courtesy of Professor Elihu Thompson of Lynn, by his electrical welding process. Such a ring about a foot in diameter allows a movement of five or six inches to one of its sides. This when wound with four or five hundred turns of No. 22 wire may be magnetically saturated by sending a current through the wire, leaving the ring charged. The terminals may now be connected with a proper galvanometer, and changes in the form will discharge the ring.

These experiments prove: —

1. That a change in the form of a magnet causes a corresponding change of stress in the field.

2. That periodic changes in form due to elasticity of form, such as are called sound vibrations, set up similar periodic changes or waves in the magnetic field.

3. That such sound vibrations of a magnet act upon other magnets like sound vibrations, and set them into corresponding vibratory movements, sympathetic or forced; sympathetic when the receiving magnet has the same pitch as the transmitting magnet, and forced when it has not the same pitch.

4. That such sound vibrations in the receiving magnet cause a corresponding change of form in its magnetic field, which manifests itself by electric currents in circuits surrounding it.

Sir William Thomson has frequently said that he could understand a mechanical idea when he could make a model of it, but could not otherwise. If one assumes that the ultimate atoms of iron are magnets, as is thought most probable now, — or holds, by Ampere's hypothesis, that currents of electricity circulate about each atom, making it

a magnet, — in either case, each individual atom has its own magnetic field, which is, necessarily, always with it. It is really its reaction upon the ether. If such atoms be elastic, as there is the best of reasons for believing, then it follows that impact must set them into periodic vibratory motion, that is, periodic change of form at a rate depending upon its degree of density and elasticity. Such changes of form set up corresponding periodic waves in the ether, as changes in the magnetic field, and these are transmitted outwards with a rate depending upon the properties of the ether to transmit such motions, not upon the source of the disturbance.

Such vibratory motions among atoms and molecules we call heat, and such periodic waves in the ether we call light, and thus Maxwell's idea of light being an electro-magnetic phenomenon is altogether in accordance with the experiments. For waves of the lengths of light waves, it is essential that the vibrating body be small and highly elastic. Maxwell's idea was, that the opposite phases of ether waves could produce opposite electrical effects, so that each half-vibration represented either positive or negative conditions; and these implied, though I have not noticed the statement, that they must have originated with vibrating magnetic atoms or molecules. It has been difficult or impossible heretofore to imagine how ether waves could be set up by vibrations of the elements, though the idea that the atoms of matter are magnets is not new at all, and has a good degree of probability. If one is to picture to himself at all how this kind of a phenomenon can occur, he is bound to have in mind some form for an atom that shall at the same time be a consistent magnetic form. If atoms are magnets, it is wellnigh inconceivable that they should be spheres or cubes, or tetrahedra or disks, or any of the ordinary geometric forms, for such would be very poor forms to exhibit magnetic properties. But a ring presents a very different case, as a ring magnet is the most perfect form possible. There is this to be said of such a form, however. It does not present what we commonly call a magnetic field; it is a closed circuit. Nevertheless, I would ask if it is probable that the ether external to a magnet of that form should be quite unaffected, quite neutral. I should suppose not, but, on the contrary, should look for some sort of stress there, though it might be of somewhat different nature, and have somewhat different properties, from an ordinary magnetic field. But if such were the case, it follows that any magnetic change in the ring magnet itself would be followed by a corresponding change in the external field, and vibratory motions would necessarily set up waves in that field. Such

waves would have a magnetic origin, but the waves themselves would not necessarily give rise to electro-magnetic effects directly. Indirectly they would, for if they could make another similar magnet vibrate sympathetically, these vibrations would react upon its magnetic properties.

Such a ring form as I have shown suggests at once the Vortex Ring theory of atoms, of the properties of which I have so often spoken to the Academy. Perhaps the experiments should have a different interpretation from that suggested here, but whatever their interpretation may be, they are believed to be entirely new, and therefore of interest, if not important.

XXI.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE.

XXIII. — PRELIMINARY NOTICE ON BUDDING IN BRYOZOA.

By C. B. Davenport.

Presented February 11, 1891, by E. L. Mark.

Since several months must elapse before the publication of my studies on Budding in Bryozoa, it has been thought best to present, in a preliminary communication, some of the more important facts gained.

In my paper on *Cristatella*,* I described for that genus a mass of cells lying between the ectoderm and muscularis which gave rise, by active cell proliferation at certain regions, to the inner layer of the polypide, — the layer from which the inner lining of the kamptoderm, the outer layer of the tentacles, the nervous system, and the digestive epithelium arise. This inner layer has been brought into prominence by the conceptions of Hatschek concerning its significance, — conceptions which appear to have influenced some of his followers in their study of marine Bryozoa. According to Hatschek, this inner layer is to be regarded as entodermic in origin, and to give rise to the digestive epithelium only. The latter part of this view is certainly incorrect, as shown by the concurrent testimony of Braem and myself. It remained, however, to determine the *origin* of the layer, or rather of the stolonic mass from which it arises. The "stolonic mass" arises in the embryo, soon after the completion of the two-layered condition, from the ectoderm, at the same pole as that at which the so-called gastrulation takes place. A disk of cells sinks below the general level of the ectoderm and becomes overgrown by that layer. This disk expands rapidly at the base of the ectoderm, and in all directions of the plane, by cell proliferation, and gives rise to the first polypides. The first two

* Cristatella: the Origin and Development of the Individual in the Colony. Bull. of the Museum of Comp. Zoöl. at Harvard College, Vol. XX. No. 4, November, 1890.

polypides, one of which is slightly older than the other, arise so that their anal surfaces are turned towards each other.

The cœlomic epithelium arises by a sort of ingression, as observed by Korotneff, and is to be regarded, probably, as mesoderm plus entoderm, the entoderm being reduced to a still more rudimentary condition than in Gymnolæmata.

In *Plumatella*, the inner layer of the primary polypide arises near the pole of ingression directly from the outer layer of the two-layered sac, and not from a mass which has already lost its connection with the outer layer, as in Cristatella. The second polypide arises at some distance from and wholly independently of the first, and, like it, by an invagination of the body-wall near the pole of ingression. The remainder of the polypides are derived from the indifferent cells about and in the neck of these two primary ones.

The method of origin of the primary polypides is fundamentally the same in both genera, but the conditions in Plumatella are to be regarded as the more primitive. In both, the inner layer of the polypide is derived from the neutral region of the outer larval layer whence the inner larval layer has arisen. Possibly this region should be regarded as neither ectoderm nor entoderm, but as still indifferent, and capable of giving rise to either.

The origin of the primary bud in Gymnolæmata also is probably to be referred to the pole of ingression or invagination, but owing to greater difficulties of orientation this cannot be determined so easily as in Phylactolæmata.

My studies on and drawings of *Paludicella* were already nearly completed when I first saw Braem's "Untersuchungen über die Bryozoen des süssen Wassers," in Bibliotheca Zoologica, Heft VI., 1891. With great keenness, he has been able, even by the study of the living animal, to correct some errors of previous authors, and he has anticipated some of my observations.

Each young polypide arises in the adult colony independently of any older polypide, from a mass of embryonic, rapidly dividing tissue at the tip of the branch, and some of this tissue is left behind as the tip moves forward. Typically, three masses of such tissue are left behind, at intervals corresponding to the joints of the branch. Of these three masses, one, the median, gives rise directly to the youngest polypide of the ancestral branch. The other two lie about 90° to the right and left of the median bud, and remain in a quiescent state until the median bud has attained a considerable size. The cells of these lateral masses are always distinguishable from those of the adjacent

body-wall by their cuboid form. They finally give rise to lateral branches, in which polypides are secondarily developed.

Braem has offered the ingenious hypothesis that the tip of the branch is to be regarded as having been occupied, ancestrally, by a polypide which has cœnogenetically disappeared. Young polypides are on this assumption derived from the neck of older ones, as in Phylactolæmata. This hypothesis is rendered less necessary, if one conceives that in the budding process the younger bud is not derived from the older, but that *they are successively derived from the same mass of embryonic tissue*, — a view which I have already maintained concerning Phylactolæmata. *The tip of the branch is*, to my mind, *to be regarded as a stolon in both the median and lateral branches.* To form the *polypide*, the two layers of the embryonic mass of the wall are, in Paludicella, invaginated into the cœlom. But some of the cells remain in their indifferent condition as the neck of the polypide.

As Braem saw in the living animal, and as my sections and reconstructions sufficiently demonstrate, the hinder part of the alimentary tract arises in a manner comparable with that in Phylactolæmata, and its formation progresses from the anal towards the oral end. The œsophagus arises independently, and later the two pockets fuse to form the completed alimentary tract. The tentacles arise somewhat differently from those of Phylactolæmata, and in the manner recently described by Seeliger for Bugula, and they as well as the kamptoderm are here two-layered. They lie at first in two parallel rows of seven each. The anus is not removed outside the tentacular corona until the two posterior free ends of the ring canal meet and become confluent between mouth and anus. An odd tentacle, younger than the others, often arises directly oralwards of the anus. The brain arises as in Cristatella, and sends out two large circumœsophageal processes to form the commissure. The so-called *epistome* of Korotneff, Nitsche, and Seeliger, which they have believed to exist in the early stages of different Gymnolæmata, is merely the fold separating the brain cavity from the œsophagus, and has no relation to the epistome of Phylactolæmata or Endoprocta. I have found no trace of a true epistome at any stage. The body-wall is invaginated at the neck of the polypide, and the latter extends as a long cylinder for some distance below the general surface. It secretes the chitinous rods and cuticula of the adult "neck." The "collare setosum" appears to split off from the thick cuticula of the neck as a delicate chitinous cylinder, which has its distal end free and its proximal end embedded in the cells of the neck immediately around the atrial opening. From its

method of origin and structure, one finds it difficult to concur with the suggestion of Professor Ehlers, that the collare setosum of Ctenostomata is homologous with the cirri of Endoprocta. Muscles and funiculi both arise from the cells of the cœlomic epithelium. The communication plates arise as a circular fold of the body-wall. The cells of the cœlomic epithelium which immediately surround the central pole become metamorphosed at their inner ends to form the teeth of the central sieve.

The polypides of the *Bicellariidæ*, *Membraniporidæ*, and *Alcyonidiidæ* arise in a similar manner to those of Paludicella; that is, from a mass of indifferent cells at the margin of the colony, — a mass from which the body-wall also is derived. The polypide arises in all cases by an invagination of the body-wall, which is two-layered at the margin of the colony. In all cases studied, the whole of the polypide is derived from this one rudiment. The alimentary tract arises, at least in some cases, exactly as in Paludicella. The ganglion arises from the inner layer of the bud, by an evagination of the floor of the atrium in both Ctenostomata and Cheilostomata, and I have found no trace of a genuine epistome at any stage.

Budding in marine Gymnolæmata seems to occur in accordance with certain laws, which may be deduced from a study of erect colonies like *Bugula*. In Bugula turrita, Verrill, we have a colony with an erect axis and branches whose points of insertion lie in a right or left handed spiral. The phyllotactic arrangement of the branches is not an invariable one, but is approximately $\frac{3}{8}$. Each branch is fan-shaped, the handle being the point of attachment, and is slightly concave toward the axis, like the thread of an Archimedean screw. The fans at the base of the colony are largest and oldest, at the tip youngest. The individuals are arranged end to end, in lines which spring from the single most proximal individual, and increase in number as upon this and the successively more distal individuals lateral as well as terminal buds arise. Sometimes, however, but one new bud — a terminal one — arises. The branches are not wholly separate from each other, but cling together in pairs.

The following laws of growth have been deduced: — 1. The individuals "break joints." 2. The lateral buds are formed earlier, and do not extend so far distally as the terminal buds. 3. When a terminal and lateral bud attached to the same proximal individual are each immediately followed by two buds, the two lateral buds lie adjacent, the two terminals outside. 4. Lateral buds tend to arise at the same time on two branches which spring from a common individual. 5. Law 4 is modified by a superior one, according to which lateral buds arise

more frequently at the edges of the fans than elsewhere. 6. The marginal branches are shortest, the middle ones longest. 7. There is one proximal individual to each "fan." This is followed by two, and these by four, of which four the two inner adjacent are lateral, the two outside ones terminal. Then each of the two outside individuals of these four bears more individuals, counting all which are formed between it and the periphery, than does each of the inner individuals. 8. New individuals are constantly being formed at the periphery of the fan, and at about the same time, but on some branches only one new bud arises, on others two. The tendency to give rise to two buds decreases as the fan grows older; and if a number of arcs be struck across an accurate drawing of an entire fan, with the proximal individual as a centre and with different radii, it will be found that the number of individuals cut by any linear unit of arc is the same for all radii.

In Bugula flabellata the fans are not attached to an erect axis, but are each attached to the rock or woodwork by their proximal individual. Three or five branches are united together, instead of two, as in B. turrita. The above "laws" are equally applicable to this species, except that No. 4 does not apply well here, being masked by another, namely, that of the three or five branches which are united together the outer ones only give rise to lateral buds. The above rules hold for *Crisia eburnea* also, which rises erect like Bugula, and has its branches united in pairs.

In genera which, like Membranipora, Lepralia, and Escharella, form creeping colonies in which all of the branches cling together, the normal architecture of the colony is obscured by inequalities of the surface upon which it lies. But under favorable conditions there is a tendency to conform to the laws which we discover in Bugula.

Regeneration of polypides has been studied in Escharella and Flustra. In these cases regeneration occurs at one point only; namely, on the operculum immediately behind, i. e. proximad of the atrial opening. Regenerated buds thus arise in the immediate vicinity of older ones, and from those cells some of which went to form that older polypide. They are formed by an invagination of the body-wall exactly as are the old polypides. Although the cells of the operculum have lost their cuboid form, and only return to it again in giving rise to the new bud, yet the nuclei appear to remain more abundant here than elsewhere on the body-wall, and this may perhaps be considered a condition of less extensive differentiation than obtains in all other parts of the body-wall.

CAMBRIDGE, February 9, 1891.

XXII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON CHLORSULPHOPYROMUCIC ACIDS.

By Henry B. Hill and Walter S. Hendrixson.

Presented February 11, 1891.

The sulphonic acids which may be formed by the action of fuming sulphuric acids upon the several brompyromucic acids were described nearly three years ago by Hill and Palmer.* The chlorpyromucic acids, which were at that time unknown, were afterwards studied by Hill and Jackson,† and were shown to differ in certain respects quite essentially from the corresponding bromine derivatives. It therefore seemed to us advisable to study also the behavior of these acids toward fuming sulphuric acid.

β-Chlor-δ-Sulphopyromucic Acid.

β-chlorpyromucic acid dissolves readily in fuming sulphuric acid (sp. gr. 1.95), and the corresponding sulphonic acid is rapidly formed without appreciable carbonization. The β-chlorpyromucic acid itself we prepared by reducing βγ-dichlorpyromucic acid with sodium amalgam containing one per cent of sodium. Complete reduction could be effected by using one and a half times the calculated amount of amalgam, and about fifty per cent of the theoretical yield of β-chlorpyromucic acid was obtained. The β-chlor-δ-sulphopyromucic acid was isolated in the usual way, after neutralizing the diluted acid solution with baric carbonate. The free acid crystallizes in hemispherical masses of indistinct radiating needles, which deliquesce rapidly when exposed to moist air.

Baric β-Chlor-δ-Sulphopyromucate, $BaC_5HClSO_6 . 4 H_2O$.

This salt is readily soluble in hot water, more sparingly soluble in cold water, and crystallizes in prisms which contain four molecules of

* These Proceedings, xxiii. 188.

† These Proceedings, xxiv 320.

water. When exposed to the air it slowly effloresces, and loses its water readily over sulphuric acid or when heated to 100°.

I. 0.7880 grm. of salt dried by short exposure to the air gave 0.4246 grm. $BaSO_4$.
II. 0.6729 grm. air-dried salt gave 0.3631 grm. $BaSO_4$.
III. 1.5568 grm. air-dried salt lost at 100° 0.2547 grm. H_2O.
IV. 1.1932 grm. air-dried salt lost over H_2SO_4 0.1935 grm. H_2O.

	Calculated for $BaC_5HClSO_6 . 4H_2O$.	Found. I.	II.	III.	IV.
Ba	31.60	31.63	31.72		
H_2O	16.61			16.36	16.22

I. 0.6958 grm. salt dried at 100° gave 0.4477 grm. $BaSO_4$.
II. 1.0371 grm. salt dried over H_2SO_4 gave 0.6678 grm. $BaSO_4$.

	Calculated for BaC_5HClSO_6	Found. I.	II.
Ba	37.89	37.83	37.86

The solubility of the salt in cold water we determined in the usual way.

I. 15.6246 grm. solution saturated at 20° gave 0.1888 grm. $BaSO_4$.
II. 17.2519 grm. solution saturated at 20° gave 0.2084 grm. $BaSO_4$.

The solution saturated at 20° therefore contained the following percentages of the anhydrous salts :—

I.	II.
1.87	1.87

Plumbic β-Chlor-δ-Sulphopyromucate, $PbC_5HClSO_6 . 4H_2O$.

The lead salt is readily soluble in hot water, more sparingly soluble in cold water, and crystallizes when its hot aqueous solution is cooled in thick rhombic prisms which contain four molecules of water. The salt effloresces slowly when exposed to the air, loses the greater part of its water over sulphuric acid, and becomes anhydrous when heated to 125°.

I. 0.7342 grm. air-dried salt gave 0.4416 grm. $PbSO_4$.
II. 1.7839 grm. air-dried salt lost at 125° 0.2552 grm. H_2O.
III. 0.7343 grm. air-dried salt lost at 125° 0.1045 grm. H_2O.

	Calculated for PbC_5HClSO_6 $4H_2O$	Found. I	II.	III.
Pb	41.11	41.09		
H_2O	14.30		14.31	14.23

I. 0.6298 grm. salt dried at 125° gave 0.4416 grm. $PbSO_4$.
II. 0.6611 grm. salt dried at 125° gave 0.4634 grm. $PbSO_4$.

	Calculated for PbC_5HClSO_6	Found. I.	II.
Pb	47.97	47.88	47.88

Potassic β-Chlor-δ-Sulphopyromucate, $K_2C_5HClSO_6 . H_2O$.

The potassium salt was readily soluble even in cold water, but was obtained by cooling a hot concentrated aqueous solution in the form of transparent prisms, which effloresced over sulphuric acid.

I. 0.7895 grm. air-dried salt gave 0.4260 grm. K_2SO_4.
II. 1.7840 grm. air-dried salt lost at 110° 0.1104 grm. H_2O.

	Calculated for $K_2C_5HClSO_6 . H_2O$	Found. I.	II.
K	24.39	24.22	
H_2O	5.61		6.18

I. 0.9626 grm. salt dried at 110° gave 0.5464 grm. K_2SO_4.
II. 0.7043 grm. salt dried at 110° gave 0.4003 grm. K_2SO_4.

	Calculated for $K_2C_5HClSO_6$	Found. I.	II.
K	25.83	25.48	25.52

While there could be little doubt of the constitution of the sulphonic acid formed from β-chlorpyromucic acid, we attempted to establish more definitely the position of its sulpho group by reducing it to the δ-sulphopyromucic acid. We found, however, that the chlorine was much more firmly held than the bromine of the corresponding β-brom-δ-sulphopyromucic acid, and that the reduction could not be effected by the ordinary reducing agents. Zinc dust in an ammoniacal solution, which had given satisfactory results with the bromsulphopyromucic acids, removed the chlorine so slowly that, even after boiling the solution for days, the reduction was far from complete. On the other hand, sodium amalgam added to the aqueous solution of the barium salt at once attacked the sulpho group, baric sulphite was precipitated, and β-chlorpyromucic acid was formed. With other reducing agents in acid solution we were equally unsuccessful. The ready elimination of the sulpho group by the action of sodium amalgam in alkaline solution was so unexpected that we were led to examine the behavior of other sulphopyromucic acids under the same conditions. We found that δ-sulphopyromucic acid was thus readily reduced to pyromucic acid, while β-sulphopyromucic acid was apparently unaffected, and that

the halogen derivatives of these two acids which we had at our disposal showed precisely the same difference in behavior. The removal of the sulpho group from the chlorsulphopyromucic acid in question may therefore be taken as evidence that the sulpho group is in the δ position.

Action of Bromine.

Like all the derivatives of δ-sulphopyromucic acid which have thus far been examined, β-chlor-δ-sulphopyromucic acid is at once oxidized by bromine in aqueous solution, and sulphuric acid is formed. Bromine was added in slight excess to a solution of the barium salt of the acid, the baric sulphate removed by filtration, and the acid filtrate extracted with ether. The acid thus obtained was very readily soluble in water and practically insoluble in benzol. After recrystallization from water it was dried and washed with benzol. The acid thus purified melted at 188°, and with the quantity at our command we found it impossible to raise this melting point. Although chlorfumaric acid melts at 191°,* there can be no doubt that chlorfumaric acid had been found in the reaction.

Action of Nitric Acid.

Like the brom-δ-sulphopyromucic acids, the β-chlor-δ-sulphopyromucic acid is readily converted into the corresponding nitro-acid by the action of fuming nitric acid. For its preparation we dissolved the dry sulphonic acid in cold fuming nitric acid, warmed the solution for some time upon the water bath, and finally evaporated the nitric acid at a gentle heat. The crystalline product thus obtained was recrystallized first from water, then from benzol, and finally from water. The β-chlor-δ-nitropyromucic acid is readily soluble in hot water, sparingly soluble in cold water, and crystallizes in thick clustered needles. By the slow cooling of the hot solution, or by spontaneous evaporation of the solution, well formed monoclinic (?) prisms with bevelled ends are obtained. The crystallized acid contains one molecule of water, part of which at least it loses over sulphuric acid, and the whole of which may be driven off at 75°. The anhydrous acid melts at 140–141°.

1.4274 grm. air-dried substance lost at 75° 0.1281 grm. H_2O.

	Calculated for $C_5H_2ClNO_5 . H_2O$.	Found.
H_2O	8.59	8.97

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* Kauder, Journal für prakt. Chemie, [2.] xxxi. 28.

I. 0.2623 grm. substance dried at 75° gave 0.1970 grm. AqCl.

II. 0.2070 grm. substance dried at 75° gave 13.8 c.c. of moist nitrogen at 25° under a pressure of 762 mm.

	Calculated for $C_5H_2ClNO_5$.	Found. I.	II.
Cl	18.54	18.57	
N	7.31		7.45

$\beta\gamma$-Dichlor-δ-Sulphopyromucic Acid.

$\beta\gamma$-dichlorpyromucic acid dissolves without charring in fuming sulphuric acid, and in the course of a few hours is converted into the corresponding sulphonic acid. The barium salt obtained by neutralizing the diluted solution with baric carbonate is quite readily soluble in cold water, but it can be purified without difficulty by recrystallization from hot water. The free acid crystallizes in indistinct radiating needles, and deliquesces rapidly when exposed to the air.

Baric $\beta\gamma$-Dichlor-δ-Sulphopyromucate, $BaC_5Cl_2SO_6 . 5\,H_2O$.

This salt is very readily soluble in hot water, less soluble in cold water, and separates as the hot solution cools in globular aggregations of radiating needles which contain five molecules of water. The salt is permanent in the air, but slowly effloresces over sulphuric acid. It loses a part of its water at 100°, but a temperature of 180° appears to be necessary for complete dehydration.

I. 0.4258 grm. air-dried salt gave 0.2045 grm. $BaSO_4$.

II. 1.0938 grm. air-dried salt gave 0.5239 grm. $BaSO_4$.

III. 1.5844 grm. air-dried salt lost at 185° 0.2930 grm. H_2O.

IV. 0.9712 grm. air-dried salt lost at 190° 0.1792 grm. H_2O.

	Calculated for $BaC_5Cl_2SO_6 . 5\,H_2O$.	Found. I.	II.	III.	IV.
Ba	28.19	28.23	28.16		
H_2O	18.52			18.49	18.45

I. 1.0167 grm. salt dried at 185° gave 0.5970 grm. $BaSO_4$.

II. 0.6549 grm. salt dried at 190° gave 0.3837 grm. $BaSO_4$.

	Calculated for $BaC_5Cl_2SO_6$	Found. I.	II.
Ba	34.59	34.52	34.44

The solubility of the salt in cold water was also determined in the usual manner.

I. 18.7100 grm. solution saturated at 18° gave 1.0970 grm. $BaSO_4$.

II. 21.2012 grm. solution saturated at 18° gave 1.2458 grm. $BaSO_4$.

The aqueous solution saturated at 18° therefore contained the following percentages of the anhydrous salt: —

I.	II.
9.97	9.98

Plumbic βγ-Dichlor-δ-Sulphopyromucate, $PbCl_5Cl_2SO_6 . 3 H_2O$.

The lead salt is readily soluble in hot water, more sparingly soluble in cold water, and separates on cooling its concentrated aqueous solution in masses of fine needles.

I. 0.5342 grm. air-dried salt gave 0.3106 grm. $PbSO_4$.
II. 0.5524 grm. air-dried salt gave 0.3212 grm. $PbSO_4$.
III. 1.1523 grm. air-dried salt lost at 160° 0.1163 grm. H_2O.
IV. 1.2621 grm. air-dried salt lost at 160° 0.1286 grm. H_2O.

	Calculated for $PbC_5Cl_2SO_6 . 3 H_2O$	Found. I	II.	III	IV.
Pb	39.81	39.72	39.73		
H_2O	10.39			10.09	10.19

I. 0.4520 grm. salt dried at 160° gave 0.2910 grm. $PbSO_4$.
II. 0.6342 grm. salt dried at 160° gave 0.4107 grm. $PbSO_4$.

	Calculated for $PbC_5Cl_2SO_6$.	Found. I.	II.
Pb	44.42	43.98	44.24

Potassic βγ-Dichlor-δ-Sulphopyromucate, $K_2C_5Cl_2SO_6 . H_2O$.

This salt we made by precipitation with potassic carbonate from the barium salt. It was readily soluble even in cold water, and crystallized in needles which contained one molecule of water. The air-dried salt lost nothing over sulphuric acid.

I. 0.6161 grm. air-dried salt gave 0.3017 grm. K_2SO_4.
II. 0.6722 grm. air dried salt gave 0.3299 grm. K_2SO_4.
III. 1.4226 grm. air-dried salt lost at 160° 0.0686 grm. H_2O.

	Calculated for $K_2C_5Cl_2SO_6\ H_2O$	Found. I.	II.	III.
K	22.02	21.99	22.04	
H_2O	5.07			4.82

I. 0.6218 grm. salt dried at 160° gave 0.3200 grm. K_2SO_4.
II. 0.7197 grm. salt dried at 160° gave 0.3688 grm. K_2SO_4.

	Calculated for $K_2C_5Cl_2SO_6$	Found. I.	II.
K	23.19	23.10	23.01

The calcium salt of the acid is very soluble even in cold water, and it was not obtained in a crystalline form.

Action of Bromine.

$\beta\gamma$-dichlor-δ-sulphopyromucic acid and its salts are immediately oxidized by bromine in aqueous solution, with the formation of carbonic dioxide, sulphuric acid, and dichlormaleic acid. Baric $\beta\gamma$-dichlor-δ-sulphopyromucate was suspended in water and a slight excess of bromine added. Baric sulphate was at once thrown down, and from the filtered solution dichlormaleic acid was obtained by extraction with ether. From the acid the anhydride was made by sublimation and its identity established through its melting point, 119–120°.*

The formation of $\beta\gamma$-dichlor-δ-nitropyromucic acid through the action of fuming nitric acid has already been described by Hill and Jackson.†

β-Sulpho-δ-Chlorpyromucic Acid.

δ-chlorpyromucic acid was slowly added to four times its weight of fuming sulphuric acid (sp. gr. 1.95), and the solution allowed to stand for ten or twelve hours. The formation of the sulphonic acid was then complete, and on neutralizing the diluted solution with baric carbonate a barium salt was obtained which could easily be purified by recrystallization from hot water. The free β-sulpho-δ-chlorpyromucic acid crystallized in dendritic needles which under ordinary atmospheric conditions are permanent in the air.

Baric β-Sulpho-δ-Chlorpyromucate, $BaC_5HClSO_6 . 5 H_2O$.

This salt is readily soluble in hot water, and but sparingly soluble in cold water. It crystallizes in large radiating needles which are permanent in the air, but slowly loses four of its five molecules of water over sulphuric acid.

I. 0.8535 grm. air-dried salt gave 0.4411 grm. $BaSO_4$.
II. 1.6218 grm. air-dried salt gave 0.8371 grm. $BaSO_4$.
III. 1.9648 grm. air-dried salt lost at 130° 0.3893 grm. H_2O.
IV. 0.9748 grm. air-dried salt lost at 150° 0.1927 grm. H_2O.
V. 1.9953 grm. air-dried salt lost at 140° 0.3936 grm. H_2O.

	Calculated for $BaC_5HClSO_6 . 5 H_2O$.	Found. I.	II.	III.	IV.	V.
Ba	30.34	30.38	30.35			
H_2O	19.93			19.81	19.76	19.73

* Ciamician and Silber, Berichte d. deutsch. chem. Gesellsch., xvi. 2396.
† These Proceedings, xxiv. 361.

1.5355 grm. air-dried salt lost over H_2SO_4 0.2467 grm. H_2O.

	Calculated for $BaC_5HClSO_6 . 5 H_2O$.	Found.
$4 H_2O$	15.95	16.06

I. 1.5480 grm. salt dried at 130° gave 0.9992 grm. $BaSO_4$.
II. 1.2325 grm. salt dried at 140° gave 0.7866 grm. $BaSO_4$.

	Calculated for BaC_5HClSO_6.	Found. I.	II.
Ba	37.89	37.96	37.52

The solubility of the salt in cold water was determined in the usual way.

I. 35.0277 grm. solution saturated at 18° gave 0.3817 grm. $BaSO_4$.
II. 27.2112 grm. solution saturated at 18° gave 0.2985 grm. $BaSO_4$.

The solution saturated at 18° therefore contained the following percentages of the anhydrous salt: —

I.	II.
1.69	1.70

Acid Baric β-Sulpho-δ-Chlorpyromucate, $Ba(C_5H_2ClSO_6)_2 . 4 H_2O$.

This salt was made by mixing solutions of the neutral barium salt and the free acid in equivalent quantities. It proved to be quite readily soluble in cold water, much more freely soluble in hot water, and separated on cooling in well formed rhombic prisms which were permanent in the air and lost nothing over sulphuric acid.

I. 0.6413 grm. air-dried salt gave 0.2261 grm. $BaSO_4$.
II. 0.6463 grm. air-dried salt gave 0.2281 grm. $BaSO_4$.
III. 1.7167 grm. air-dried salt lost at 125° 0.1855 grm. H_2O.

	Calculated for $Ba(C_5H_2ClSO_6)_2 . 4 H_2O$.	Found. I.	II.	III.
Ba	20.76	20.72	20.75	
H_2O	10.91			10.81

I. 0.7345 grm. salt dried at 125° gave 0.2900 grm. $BaSO_4$.
II. 0.7734 grm. salt dried at 125° gave 0.3052 grm. $BaSO_4$.

	Calculated for $Ba(C_5H_2ClSO_6)_2$	Found I.	II.
Ba	23.30	23.21	23.20

The solubility of the salt in cold water was also determined.

I. 6.7510 grm. solution saturated at 20° gave 0.1935 grm. $BaSO_4$.
II. 5.6625 grm. solution saturated at 20° gave 0.1627 grm. $BaSO_4$.

The solution saturated at 20° therefore contained the following percentages of the anhydrous salt: —

I.	II.
7.23	7.24

Calcic β-Sulpho-δ-Chlorpyromucate, $CaC_5HClSO_6 . 2 H_2O$.

The calcium salt crystallizes in transparent prisms which contain two molecules of water. It is permanent in the air or over sulphuric acid, and requires a high temperature for complete dehydration. The salt dried at 200° showed no signs of decomposition.

I. 0.9321 grm. air-dried salt gave 0.4166 grm. $CaSO_4$.
II. 0.8489 grm. air-dried salt gave 0.3784 grm. $CaSO_4$.
III. 1.6243 grm. air-dried salt lost at 200° 0.1904 grm. H_2O.

	Calculated for $CaC_5HClSO_6 . 2 H_2O$.	Found. I.	II.	III.
Ca	13.31	13.14	13.11	
H_2O	11.98			11.72

I. 0.5804 grm. salt dried at 200° gave 0.2956 grm. $CaSO_4$.
II. 0.7000 grm. salt dried at 200° gave 0.3566 grm. $CaSO_4$.

	Calculated for CaC_5HClSO_6	Found. I.	II.
Ca	15.12	14.98	14.98

Plumbic β-Sulpho-δ-Chlorpyromucate, $PbC_5HClSO_6 . H_2O$.

This salt is sparingly soluble in cold water, more readily soluble in hot water, and crystallizes in compact clusters of radiating prisms. It loses nothing over sulphuric acid, or when heated to 100°.

I. 0.5646 grm. air-dried salt gave 0.3799 grm. $PbSO_4$.
II. 0.6672 grm. air-dried salt gave 0.4485 grm. $PbSO_4$.
III. 1.6403 grm. air-dried salt lost at 165° 0.0705 grm. H_2O.
IV. 1.5787 grm. air-dried salt lost at 160° 0.0631 grm. H_2O.
V. 1.6982 grm. air-dried salt lost at 160° 0.0629 grm. H_2O.

	Calculated for $PbC_5HClSO_6 . H_2O$.	Found. I.	II.	III.	IV.	V.
Pb	46.06	45.95	45.93			
H_2O	4.00			4.29	3.99	3.70

I. 0.5240 grm. salt dried at 165° gave 0.3690 grm. $PbSO_4$.
II. 1.0133 grm. salt dried at 160° gave 0.7118 grm. $PbSO_4$.
III. 0.5399 grm. salt dried at 160° gave 0.3791 grm. $PbSO_4$.

	Calculated for PbC_5HClSO_6.	Found. I.	II.	III.
Pb	47.98	48.10	48.01	47.96

Potassic β-Sulpho-δ-Chlorpyromucate, $K_2C_5HClSO_6$.

The potassium salt crystallizes in long needles which are anhydrous.

I. 0.9272 grm. air-dried salt gave 0.5309 grm. K_2SO_4.
II. 0.8955 grm. air-dried salt gave 0.5126 grm. K_2SO_4.
III. 0.7962 grm. air-dried salt gave 0.4562 grm. K_2SO_4.

	Calculated for $K_2C_5HClSO_6$.	Found. I.	II.	III.
K	25.84	25.70	25.70	25.73

Although there could be little doubt that the sulphonic acid formed from δ-chlorpyromucic acid was identical in structure with the β-sulpho-δ-brompyromucic acid of Hill and Palmer,* we wished to prove this identity more rigorously by preparing from it by reduction the β-sulphopyromucic acid. We found that the method employed by Hill and Palmer in the reduction of the bromine compound could successfully be employed in this case, although the chlorine was replaced with much greater difficulty, and long continued boiling of the ammoniacal solution with zinc dust was essential for complete reduction. We also found it advantageous to convert the baric β-sulphopyromucate into the acid salt, and to purify this by recrystallization from hot water. The neutral salt was crystallized for analysis by evaporation *in vacuo* over sulphuric acid.

I. 0.7039 grm. air-dried salt gave 0.4287 grm. $BaSO_4$.
II. 1.0434 grm. air-dried salt lost at 160° 0.1476 grm. H_2O.

	Calculated for $BaC_5H_2SO_6 . 3H_2O$.	Found. I.	II.
Ba	35.96	35.80	
H_2O	14.18		14.15

0.8946 grm. salt dried at 160° gave 0.6347 grm. $BaSO_4$.

	Calculated for $BaC_5H_2SO_6$.	Found.
Ba	41.90	41.72

The solubility of the salt in cold water was determined by the usual method.

I. 14.4785 grm. solution saturated at 21° gave 0.1960 grm. $BaSO_4$.
II. 12.0525 grm. solution saturated at 21° gave 0.1628 grm. $BaSO_4$.

The solution saturated at 21° therefore contained the following percentages of the anhydrous salt: —

* These Proceedings, xxiii. 214.

I.	II.
1.90	1.90

These results agree exactly with those obtained by Hill and Palmer for β-sulphopyromucic acid, and the relative position of the sulpho group is thus established with precision.

Action of Bromine.

β-sulpho-δ-chlorpyromucic acid is readily oxidized in aqueous solution by bromine, carbonic dioxide is liberated, but little or no sulphuric acid is formed even when the action is long continued at 100°. With an excess of bromine, an acid is formed which is undoubtedly identical with the sulphofumaric acid described by Hill and Palmer,* while a derivative of furfuran-β-sulphonic acid is formed in nearly theoretical quantity, if but a single molecule of bromine is added. For its preparation we passed into a cold aqueous solution of baric β-sulpho-δ-chlorpyromucate the vapor of the calculated weight of bromine by means of a current of air, and evaporated to a small volume the feebly acid solution thus obtained. The barium salt of the $\alpha\alpha$-chlorbromfurfuran-β-sulphonic acid which was thus obtained could then be purified by recrystallization. By evaporation in desiccator the free acid was obtained as a waxy deliquescent mass, which showed but slight indications of crystalline structure.

Baric αα-Chlorbromfurfuran-β-Sulphonate, $Ba(C_4HClBrSO_4)_2 . H_2O$.

This salt is readily soluble in hot water, less soluble in cold water, and separates in pearly plates when its hot solution is quickly cooled. A cold solution by spontaneous evaporation deposits this salt in clusters of radiating needles.

I. 0.8479 grm. air-dried salt gave 0.2936 grm. $BaSO_4$.
II. 0.5210 grm. air-dried salt gave 0.1797 grm. $BaSO_4$.
III. 1.1406 grm. air-dried salt lost at 120° 0.0314 grm. H_2O.
IV. 1.6890 grm. air-dried salt lost at 138° 0.0491 grm. H_2O.

	Calculated for $Ba(C_4HClBrSO_4)_2 . H_2O$.	Found. I.	II.	III.	IV.
Ba	20.27	20.35	20.28		
H_2O	2.66			2.75	2.90

I. 0.7017 grm. salt dried at 138° gave 0.2496 grm. $BaSO_4$.
II. 0.9112 grm. salt dried at 138° gave 0.3259 grm. $BaSO_4$.
III. 0.7824 grm. salt dried at 130° gave 0.2795 grm. $BaSO_4$.

* These Proceedings, xxiii. 211.

	Calculated for $Ba(C_4HClBrSO_4)_2$.	Found. I.	II.	III.
Ba	20.82	20.92	21.03	21.00

The solubility of the salt in cold water was also determined in the usual way.

I. 20.5274 grm. solution saturated at 18° gave 0.3105 grm. $BaSO_4$.
II. 21.5098 grm. solution saturated at 18° gave 0.3276 grm. $BaSO_4$.

The solution saturated at 18° therefore contained the following percentages of the anhydrous salt: —

I.	II.
4.27	4.30

Calcic αα-Chlorbromfurfuran-β-Sulphonate, $Ca(C_4HClBrSO_4)_2 . 2 H_2O$.

The calcium salt crystallizes in large concentrically grouped needles which contain two molecules of water. It is permanent in the air or over sulphuric acid.

I. 0.6429 grm. air-dried salt gave 0.1480 grm. $CaSO_4$.
II. 0.7372 grm. air-dried salt gave 0.1702 grm. $CaSO_4$.
III. 0.7580 grm. air-dried salt lost at 160° 0.0468 grm. H_2O.

	Calculated for $Ca(C_4HClBrSO_4)_2 . 2 H_2O$.	Found. I.	II.	III.
Ca	6.70	6.77	6.79	
H_2O	6.03			6.17

I. 0.4463 grm. salt dried at 160° gave 0.1097 grm. $CaSO_4$.
II. 0.4230 grm. salt dried at 165° gave 0.1045 grm. $CaSO_4$.

	Calculated for $Ca(C_4HClBrSO_4)_2$.	Found. I.	II.
Ca	7.13	7.23	7.26

Plumbic αα-Chlorbromfurfuran-β-Sulphonate, $Pb(C_4HClBrSO_4)_2 . H_2O$.

The lead salt is but sparingly soluble in cold water, and its solubility is but little increased by heat. By evaporation *in vacuo* over sulphuric acid it was obtained in compact hemispherical masses. The salt may be dried without decomposition at 100°, but at a somewhat higher temperature it begins to decompose, and at 140° it is completely charred.

I. 0.5743 grm. air-dried salt gave 0.2339 grm. $PbSO_4$.
II. 1.5077 grm. air-dried salt lost at 100° 0.0410 grm. H_2O.

	Calculated for $Pb(C_4HClBrSO_4)_2 . H_2O$.	Found I.	Found II.
Pb	27.75	27.83	
H_2O	2.41		2.72

0.7187 grm. salt dried at 100° gave 0.3000 grm. $PbSO_4$.

	Calculated for $Pb(C_4HClBrSO_4)_2$.	Found.
Pb	28.39	28.52

Potassic αα-Chlorbromfurfuran-β-Sulphonate, $KC_4HClBrSO_4$.

The potassium salt is very soluble in hot water, less soluble in cold water. The hot concentrated solution solidifies on cooling, with the separation of small shining anhydrous plates.

I. 0.5801 grm. air-dried salt gave 0.1699 grm. K_2SO_4.
II. 0.5479 grm. air-dried salt gave 0.1625 grm. K_2SO_4.

	Calculated for $KC_4HClBrSO_4$.	Found I.	Found II.
K	13.05	13.15	13.31

Action of Chlorine.

We attempted to prepare αα-dichlorfurfuran-β-sulphonic acid by the action of chlorine upon the salts of β-sulpho-δ-chlorpyromucic acid. We found, however, that the reaction in this case was not as simple as that with bromine, in that the oxidation of the furfuran-sulphonic acid began long before one molecule of chlorine had been added, and that sulphofumaric acid and even sulphuric acid were formed before the whole of the original sulphochlorpyromucic acid had disappeared. While it was not difficult to isolate a salt which had substantially the properties and the composition of a baric dichlorfurfuran sulphonate, we were unable to prepare by any variation of the method a product from which we could obtain perfectly satisfactory results.

Action of Nitric Acid.

We studied the action of nitric acid upon β-sulpho-δ-chlorpyromucic acid only so far as to satisfy ourselves that no nitro-acid could be formed in this way, and that sulphofumaric acid was the chief product of the reaction.

PROCEEDINGS.

Eight hundred and twenty-third Meeting.

May 28, 1889. — Annual Meeting.

The President in the chair.

Professor Henry W. Haynes was appointed Recording Secretary *pro tempore.*

Letters were received from Henry Willey, accepting Fellowship; from the Marquis de Caligny and Professor Mendeleeff, acknowledging election as Foreign Honorary Members; from Professor David G. Lyon, resigning Fellowship; from Madame Donders, announcing the death of her husband, Franz Cornelis Donders, Foreign Honorary Member of the Academy; from Professor d'Achiardi, Secretary, announcing the death of Giuseppe Meneghini, President of the Tuscan Society of Natural Science; from the Royal Academy of Science of Turin, announcing the death of its President, Angelo Genocchi; from the Recording Secretary of the American Oriental Society, thanking the Academy for the use of its hall; and from the Botanical Society of France, inviting members of the Academy to take part in organizing a Botanical Congress at Paris in August, 1889.

The annual report of the Council was presented by the Corresponding Secretary.

The Treasurer and the Librarian presented their annual reports.

The following report was read: —

The Rumford Committee present the following report for the year ending with this Annual Meeting: —

Appropriations from the income of the Rumford Fund were recommended as follows: —

To Professor Trowbridge, $500, to assist him in his work on metallic spectra.

To Mr. W. H. Pickering, $500, to meet the expense of going to California and observing the solar corona, etc., on occasion of the total eclipse of January 1, 1889.

To Mr. C. C. Hutchins, $250, for continuing his work on lunar radiation.

To Dr. E. H. Hall, $100, for investigations on the fluctuations of temperature which occur at the inner surface of the cylinder of a steam-engine in operation.

These recommendations were approved by the Academy, and the money voted; and most of it is already paid by the Treasurer.

The Treasurer has also paid from the income of the Rumford Fund $321.65, for the medals to be presented to Professor Michelson; $56.31, for printing in the Proceedings papers on Light or Heat; and $145.90, for additions to the library on these subjects.

For the Committee,

JOSEPH LOVERING, *Chairman.*

On the motion of the Corresponding Secretary it was

Voted, To meet, on adjournment, on the 12th of June.

On the motion of the Corresponding Secretary it was

Voted, That an appropriation of twenty-five hundred dollars ($2500) be made for the expenses of publication for the ensuing year.

On the motion of the Librarian it was

Voted, That an appropriation of twelve hundred dollars ($1200) be made for the purchase and binding of books for the ensuing year.

The following gentlemen were elected members of the Academy: —

William Coe Collar, of Boston, to be a Resident Fellow in Class III., Section 2.

Horace Elisha Scudder, of Cambridge, to be a Resident Fellow in Class III., Section 4.

The annual election resulted in the choice of the following officers: —

JOSEPH LOVERING, *President.*

ANDREW P. PEABODY, *Vice-President.*

JOSIAH P. COOKE, *Corresponding Secretary.*

WILLIAM WATSON, *Recording Secretary.*

ELIOT C. CLARKE, *Treasurer.*

HENRY W. HAYNES, *Librarian.*

Council.

AMOS E. DOLBEAR,
FRANCIS H. STORER,
ARTHUR SEARLE, } of Class I.

HENRY W. WILLIAMS,
WILLIAM G. FARLOW,
SAMUEL H. SCUDDER, } of Class II.

WILLIAM EVERETT,
EDWARD J. LOWELL,
MARTIN BRIMMER, } of Class III.

Rumford Committee.

WOLCOTT GIBBS, JOSIAH P. COOKE,
EDWARD C. PICKERING, JOSEPH LOVERING,
JOHN TROWBRIDGE, GEORGE B. CLARK,
ERASMUS D. LEAVITT.

Member of the Committee of Finance.

THOMAS T. BOUVÉ.

The President appointed the following standing committees: —

Committee of Publication.

JOSIAH P. COOKE, ALEXANDER AGASSIZ,
JOHN C. ROPES.

Committee on the Library.

HENRY P. BOWDITCH, AMOS E. DOLBEAR,
EDWARD J. LOWELL.

Auditing Committee.

HENRY G. DENNY, THOMAS T. BOUVÉ.

Professor Henry B. Hill presented the following papers by title: —

Chlorpyromucic Acids. By H. B. Hill and Louis L. Jackson.

On certain Derivatives of Furfuracrylic Acid. By H. B. Gibson and C. F. Kahnweiler.

On the so-called Dioxymaleic Acid. By W. S. Hendrixson.

Professor C. Loring Jackson presented the following papers by title: —

On the Action of Sodium Malonic Ester on Tribromtrinitrobenzol. By C. L. Jackson and G. D. Moore.

On the Action of Sodium Acetacetic Ester on Tribromdinitrobenzol. By C. L. Jackson and G. D. Moore.

On the Action of Sodium Malonic Ester on Tribromdinitrobenzol. Second Paper. By C. L. Jackson and W. S. Robinson.

On certain Derivatives of Tetrabromdinitrobenzol. By C. L. Jackson and W. D. Bancroft.

On some Nitro Derivatives of Metabromtoluol. By W. B. Bentley and W. H. Warren.

Professor John Trowbridge presented the following papers by title: —

Contributions from the Jefferson Physical Labratory: — 1. On the Magnetic Properties of Nickel and Tungsten Alloys. By John Trowbridge and Samuel Sheldon. 2. On the Neutralization of Induction. By John Trowbridge and Samuel Sheldon. 3. On the Spectrum of Copper. By John Trowbridge and W. C. Sabine. 4. On Cauchy's Formula for Dispersion of Light, especially in the Ultra Violet Spectrum. By John Trowbridge and W. C. Sabine.

Dr. Harold Whiting presented the following contribution from the Jefferson Physical Labratory.

"Mr. Chittenden has constructed an air thermometer sensitive to the heat created by an alternating current passing through the human body, and showing that such a current may be as great as one hundredth of an ampere without causing excessive pain. By the same instrument the effect of a strong telephone current may be detected.

"The class in color have produced a triple composite photograph, reproducing faithfully the colors of a considerable portion of an oil painting. Specimen shown."

Eight hundred and twenty-fourth Meeting.

June 12, 1889. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The Recording Secretary being absent Mr. Eliot C. Clarke was appointed Recording Secretary *pro tempore.*

The following papers were presented: —

On a New Method of determining Gas Densities. By Josiah P. Cooke.

The *Mécanique Céleste* of Laplace, and its Translation with a Commentary by Bowditch. By Joseph Lovering.

Contributions to American Botany. Descriptions of New Species of Plants and Notes upon various Points in Connection with our Northern Flora. By Sereno Watson.

Eight hundred and twenty-fifth Meeting.

October 9, 1889. — STATED MEETING.

In the absence of the President and Recording Secretary, Dr. H. W. Williams was chosen President *pro tempore*, and Mr. H. W. Haynes, Secretary.

Voted, To adjourn to the second Wednesday in November.

Eight hundred and twenty-sixth Meeting.

November 13, 1889. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read the following letters: from the Anthropological Society of Vienna, inviting members of the Academy to attend a convention to be held at Vienna, August 5 to 10, 1889; from the Natural History Society of Emden, inviting members to be present at the celebration of its seventy-fifth anniversary, from the Executive Committee of the Engineers and Architects of Palermo, inviting the Academy to send delegates to the Seventh National and First International Congress of Engineers and Architects; from Wilhelm Weber, acknowledging his election as Foreign Honorary Member; and from Leo Lesquereux, Jr., announcing the death of Leo Lesquereux, an Associate Fellow.

On the motion of the Corresponding Secretary, it was

Voted, To meet, on adjournment, on the second Wednesday in December.

Voted, That the invitation of the American Philosophical Society be referred to the President, the Corresponding Secretary, and Professor Goodale, with full powers.

Voted, That the thanks of the Academy be returned to the Anthropological Society of Vienna, the Natural History Society of Emden, and the Congress of Engineers and Architects of Palermo.

The following papers were presented: —

On the Effects produced on some Tropical Plants by a Temperature of from 40° to 34° Fahr. By George L. Goodale.

On an Apparatus for subjecting Plants to very slight Variations of Temperature. By George L. Goodale.

Eight hundred and twenty-seventh Meeting.

December 11, 1889. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The President announced the death of Charles Deane, Resident Fellow; of Rowland G. Hazard, Alexander Johnston, Elias Loomis, Maria Mitchell, Theodore D. Woolsey, Associate Fellows, and of James Prescott Joule, Foreign Honorary Member.

The following gentlemen were elected members of the Academy: —

William Roscoe Livermore, of Cambridge, to be a Resident Fellow in Class I., Section 3.

Jean Charles Galissard de Marignac, of Geneva, to be a Foreign Honorary Member, in Class I., Section 3, in place of the late Michel Eugène Chevreul.

Mr. W. W. Jacques presented by title a paper on Telephonic Specific Induction Capacity, by F. H. Safford, and G. U. G. Holman.

Professor Cooke read a paper entitled, Examples of the obvious Influence of the Force which determines Spherical Aggregations or Concretions in solid Masses on Crystallization, and the Bearing of the Facts on the Chondritic Structure of Meteorites.

On the recommendation of the Rumford Committee, it was

Voted, To appropriate five hundred dollars ($500) from the income of the Rumford Fund to Professor Rowland, of Baltimore, for researches on metallic spectra, on condition that the printed results, wherever published, shall contain the following notice appended thereto: "Investigations on Light and Heat, made and published wholly or in part with appropriation from the Rumford Fund of the American Academy of Arts and Sciences."

Eight hundred and twenty-eighth Meeting.

January 8, 1890. — STATED MEETING.

The PRESIDENT in the chair.

The President read a letter from Mr. Edwin P. Seaver, resigning Fellowship in the Academy.

M. S. H. Scudder gave an account of an extensive discovery of fossil insects (butterflies).

Professor Dolbear made a short communication on the causes producing the present state of the weather. Remarks on this subject were made by Professor Searle, Mr. Ritchie, and the Recording Secretary.

Eight hundred and twenty-ninth Meeting.

February 12, 1890. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President read a letter from Charles de Marignac, acknowledging his election as Foreign Honorary Member; also, a circular from the Physical-Economical Society of Königsberg, inviting attendance at its centennial festival.

The following papers were presented: —

On the Construction of Languages. By Henry W. Williams.

Notes on the North American Species of Laboulbeniaceæ. By Roland Thaxter.

Eight hundred and thirtieth Meeting.

March 12, 1890. — STATED MEETING.

The PRESIDENT in the chair.

The President announced the death of William P. Atkinson, Resident Fellow.

The Corresponding Secretary read a letter from the Library Restoration Committee of the University of Toronto, announ-

cing the destruction by fire of the library of the University, and asking aid in the formation of a new collection of scientific books; and it was

Voted, That a set of the Proceedings of the Academy be presented to the University of Toronto.

The following gentlemen were elected members of the Academy: —

Charles Otis Whitman, of Worcester, to be a Resident Fellow in Class II., Section 3.

Sherburne Wesley Burnham, of San José, California, to be an Associate Fellow in Class I., Section 2, in place of the late Maria Mitchell.

William Augustus Rogers, of Waterville, Maine, to be an Associate Fellow in Class I., Section 2, in place of the late Elias Loomis.

Carl Barus, of Washington, to be an Associate Fellow in Class I., Section 3.

Frank Austin Gooch, of New Haven, to be an Associate Fellow in Class I., Section 3, in place of the late Frederick Augustus Porter Barnard.

Thomas McIntyre Cooley, of Ann Arbor, Michigan, to be an Associate Fellow in Class III., Section 1, in place of the late Rowland Gibson Hazard.

Timothy Dwight, of New Haven, to be an Associate Fellow in Class III., Section 2, in place of the late Theodore Dwight Woolsey.

Edward John Phelps, of Burlington, Vermont, to be an Associate Fellow in Class III., Section 3, in place of the late Alexander Johnston.

Eight hundred and thirty-first Meeting.

April 9, 1890. — Monthly Meeting.

In the absence of the President, Professor F. W. Putnam was chosen President *pro tempore*.

The following paper was presented: —

The Use of the Phonograph in the Preservation of the

Languages of the American Indians, with Demonstrations. By J. Walter Fewkes.

The following papers were presented by title: —

On the Carpologic Structure and Development of the Collemaceæ and Allied Groups. By W. C. Sturgis.

Concerning the Structure and Development of Tuomeya fluviatilis, Harv. By William A. Setchell.

On the Extent of the Excursion of the Electrodes of the Microphone Transmitter. By Charles R. Cross.

Eight hundred and thirty-second Meeting.

May 14, 1890. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs. Sherburne W. Burnham, Thomas M. Cooley, Timothy Dwight, Frank A. Gooch, and William A. Rogers, acknowledging their election as Associate Fellows; from George E. Ellis and Henry Willey, resigning Fellowship; and from the Secretary of the American Oriental Society, thanking the Academy for the use of its hall.

Major William R. Livermore presented a communication on the Law of Gravitation at Molecular Distances, the object of this paper being to call attention to the following proposition: — If the force which holds together the particles of a solid body varies as the product of the masses and inversely as the square of the distance, then the solid is not homogeneous, and its particles are not distributed uniformly throughout the mass, but are collected in rows or lines.

Professor Dolbear presented a short communication on the subject of Vortex Rings.

AMERICAN ACADEMY OF ARTS AND SCIENCES.

REPORT OF THE COUNCIL. — PRESENTED MAY 27, 1890.

BIOGRAPHICAL NOTICES.

WILLIAM PARSONS ATKINSON . .	By EDWARD ATKINSON, Esq.
CHARLES DEANE	Rev. A. P. PEABODY.
JOHN HUNTINGTON CRANE COFFIN	APPLETON'S ANNUAL CYCLOPÆDIA.
ROWLAND GIBSON HAZARD . . .	President ANGELL.
ALEXANDER JOHNSTON	Prof. A. T. ORMOND.
LEO LESQUEREUX	Prof. W. G. FARLOW.
ELIAS LOOMIS	Prof. H. A. NEWTON.
MARIA MITCHELL	HENRY MITCHELL, Esq.
THEODORE DWIGHT WOOLSEY . .	Prof. G. P. FISHER.
JAMES PRESCOTT JOULE	Prof. A. E. DOLBEAR.

REPORT OF THE COUNCIL.

MAY 27, 1890.

Since the last annual meeting, May 28, 1889, the Academy has lost by death nine members; — viz. two Resident Fellows, William Parsons Atkinson and Charles Deane; six Associate Fellows, John Huntington Crane Coffin, Alexander Johnston, Leo Lesquereux, Elias Loomis, and Maria Mitchell; and one Foreign Honorary Member, James Prescott Joule.

RESIDENT FELLOWS.

WILLIAM PARSONS ATKINSON.

Professor William Parsons Atkinson died on the 10th of March, 1890, after a service of fifty years as a teacher. He was the son of Amos and Anna Greenleaf Atkinson, and was born in Boston, August 20, 1820. He entered Harvard College in the class of 1838, graduating the seventh in his class.

On the 21st of June, 1843, he married Sarah Cabot Parkman, daughter of the Rev. Dr. Francis Parkman, pastor of the New North Church of Boston, who survives him. Of his four children only two are living.

He began to teach school immediately on leaving college, devoting himself mainly to preparing boys for college. On the founding of the Massachusetts Institute of Technology, in 1866, he became Professor of English Literature and History. He held this position from that time for twenty-four years, until within a year before his death, when he resigned.

During this long period of service he applied himself with entire devotion to the interests of the school, often to the injury even of his own health, doing for years such voluntary work as teaching political economy and the elements of constitutional law outside his own

special department, when the condition of the finances of the school made it impossible to provide special teachers in these subjects.

One of his early pupils, Mr. Moorfield Storey, has written these words, which leave little to be added : —

"By the death of William P. Atkinson this community has lost a man of a kind unfortunately too rare. His singular simplicity, his unswerving devotion to high ideals, his never failing courage and hopefulness, his strong sense of duty, his absolute unselfishness, were recognized by all who made his acquaintance. He was too modest even to suspect how many men whom he knew perhaps but slightly drew strength and inspiration from his example. He was simply incapable of a base or sordid thought, and no material temptation weighed for an instant with him against what he felt to be right. During the early days of antislavery agitation, he gave abundant proof of how little he valued worldly success or comfort if they were to be had only by a sacrifice of principle. As a teacher, especially during the years when he was dealing with young men, to many of whom immediate pecuniary success was important, he sought to inspire his pupils with an interest in what makes life really rich, and many of his old scholars will cherish through life a grateful recollection of their hours with him, and will appreciate more and more how much of what they most value they owe to his teaching. He showed by his whole life how devoutly he believed in 'plain living and high thinking,' and in this material age, when the community seems given over to luxury and the vow of poverty is so rarely taken, it is very hard to fill his place."

CHARLES DEANE.

Charles Deane was born at Biddeford, in the then District of Maine, on the 10th of November, 1813. His father was a physician in extensive practice, a man of liberal culture, and not without interest in the subjects of historical and antiquarian research in which his son performed pre-eminent service. Among his father's nearest neighbors was Judge George Thacher, who had been a Delegate to the Continental Congress, had at an early period represented Massachusetts in the National Congress, and was among the men who both helped in the making of history and had no little power of narrative and description. There were also in his native town and in the adjoining town of Saco several families that had been distinguished in earlier time and were rich in treasured reminiscences. Mr. Deane's

surroundings in his boyhood may, therefore, account in part for the direction given to the studies and arduous labors of his later years. He was fitted for college; but for domestic reasons his plan of life was changed, and at the age of nineteen he came to Boston as a clerk. He subsequently became a partner in the dry goods importing firm of Messrs. Waterston, Pray, & Co., and was the son-in-law of his senior partner. Meanwhile he had begun to devote his leisure to the past and the long past, and had become an active member of the Massachusetts Historical and the American Antiquarian Societies. In 1864 he retired from business, while in the full tide of success, with a fortune not so large as he saw the means of rapidly making it, but amply sufficient for elegant, liberal, and generous living, and for the easy accumulation of rare and costly books, which made his library second in its kind to hardly any in this country. From that time his sole occupation was the discovery and verification of records and facts appertaining to American history, the editing of works that had passed out of sight and almost out of knowledge, and the writing of portions of history previously unwritten or miswritten. The only break in this laborious life was a European tour in 1866, including a sojourn of several weeks in London, where his reputation had preceded him, so that he enjoyed large opportunities of intercourse with men of kindred pursuits, and gathered no little material for future use. He retained unimpaired vigor of body and mind and full working power till the winter or spring of 1889. His last illness was one of slow decline, with not infrequent suffering, and was borne with patience and serenity. His life closed on the 13th of November of that year.

For twenty-five years Mr. Deane was an officer, for a large portion of that time a Vice-President, of the Massachusetts Historical Society, and for nearly as long a time an efficient office-bearer in the American Antiquarian Society. There are few volumes of the Proceedings of either of these societies during that period that do not bear traces of his collaboration. It would be hard to say, and to one not conversant with the facts still harder to believe, how much of the most valuable matter in those volumes would have been lost but for his keenness in discovering, perseverance in procuring, and painstaking accuracy in recording or editing, obscure yet often precious materials for history. We cannot even commence the catalogue, which would fill many pages. Perhaps his most important work is his edition of Governor Bradford's "History of Plymouth Plantation." This work had long lain in manuscript in the library of the Bishop of London, and Mr. Deane first of Americans ascertained where it was to be found. He pro-

cured a transcript of it, and so edited it as greatly to enhance its value. In addition to labors peculiarly his own, he contributed to the "Memorial History of Boston" one of the most important chapters, and two chapters to the "Narrative and Critical History of America." His style was simple, chaste, and elegant, manifestly formed on the best models, and as an annotator he had the rare gift of knowing precisely what needed to be supplied or explained, and what the reader might be supposed to know or understand without prompting.

Though not a college graduate, Mr. Deane did not lack university honors. In 1856, he received from Harvard College the degree of A. M.; that of LL. D. was conferred on him by Bowdoin College in 1871, and in 1886, at the two hundred and fiftieth anniversary of the founding of Harvard College, he was selected as foremost in his department of literature for a place among the men of special eminence who then received the degree of LL. D.

Mr. Deane in private life merited and won only the highest esteem, honor, and love. He had and made a happy home, a centre of kindness and hospitality. He was generous, not only in those charities of which a man of ample means does not feel the cost, but in his unfailing readiness to aid others in their researches at the expense of time, which to him was more precious than money, and equally in his full appreciation of labors kindred to or parallel with his own, which had no more cordial welcome, and, when merited, no more hearty praise than from him. He probably never had an enemy or a detractor; while no man can have had a longer list of friends, or warmer friends than those who knew him best.

ASSOCIATE FELLOWS.

JOHN HUNTINGTON CRANE COFFIN.*

John Huntington Crane Coffin was born in Wiscasset, Maine, September 14, 1815; he died in Washington, D. C., January 8, 1890. He was graduated at Bowdoin College in 1834, and in January, 1836, entered the United States Navy as Professor of Mathematics. From 1836 till 1843 he served on board the "Vandalia" and "Constellation" of the West India squadron, at the Norfolk Navy Yard, and on

* By permission from Appleton's Annual Cyclopædia for 1890.

the Florida surveys. He was placed in charge of the mural circle in the United States Naval Observatory, Washington, in 1843, and continued in that capacity until 1853, when he was assigned to the charge of the Department of Mathematics at the United States Naval Academy in Annapolis, and later had charge of the department of astronomy and navigation. In 1865 he was appointed to the charge of the "American Ephemeris and Nautical Almanac," then issued in Cambridge, Mass., but in 1867 its place of publication was transferred to Washington, D. C., whither Professor Coffin then removed, and remained its chief officer until 1877, when he was placed on the retired list, having been senior Professor of Mathematics since 1848. The degree of LL. D. was conferred upon him by Bowdoin in 1884, and he was a member of the American Academy of Arts and Sciences, the American Philosophical Society, and in 1863 became one of the corporate members of the National Academy of Sciences, named by act of Congress, of which organization he was for several terms the treasurer. Besides many shorter articles and certain contributions to cyclopædias, Professor Coffin published "Observations with the Mural Circle at the United States Naval Observatory, with Explanations, Formulas, Tables, and Discussions, 1845–1849," in the volumes of the Observatory for those years; "The Compass" (1863); "Navigation and Nautical Astronomy" (New York, 1868); the last two were prepared for use in the United States Naval Academy; "The American Ephemeris and Nautical Almanac," edited (1868 till 1879); also "Personal Errors in Observations of the Declination of Stars," in Dr. Benjamin A. Gould's "Astronomical Journal" (1850), and "Observations of the Total Eclipse of the Sun, August, 1869," made at Burlington, Mount Pleasant, and elsewhere in Iowa, under his direction (Washington, 1884).

ROWLAND GIBSON HAZARD.*

Rowland Gibson Hazard belonged to an old Rhode Island family, whose representatives were in Newport as early as 1640. He was the son of Rowland and Mary Peace Hazard, and was born in South Kingstown, October 9, 1801. His parents were members of the Society of Friends. He received his education principally at the Friends' School in Westtown, Pa. He was an apt scholar, especially in mathematics. His father, who had long been engaged in business

* Not ready in time for the preceding Annual Report.

in Charleston, S. C., engaged in the manufacture of woollen goods in Peace Dale, R. I., in 1802. Soon after leaving school, the subject of this memoir, with his older brother, Isaac Peace, succeeded to the father's business in Peace Dale. The business rapidly expanded. In 1847 the Peace Dale Manufacturing Company was incorporated. In 1866 Mr. R. G. Hazard withdrew from the active conduct of the affairs of the company, and left them in the hands of his two sons. He brought to the prosecution of business the greatest activity and energy.

He was always deeply interested in whatever conduced to the prosperity of his town and of his State, and to the welfare of humanity. He was active in promoting the growth of free schools in Rhode Island, and in elevating public morals. He presented his town with a free town-hall. Once, when in New Orleans, he with the aid of Jacob Barker secured the release of a Rhode Island negro and other black freemen from the chain-gang to which they had been unjustly condemned, though his action was not unattended with peril to himself. He was a member of the General Assembly of Rhode Island for several terms, serving in both houses. While there, he opposed with great vigor the practice by railroads of charging higher proportionate rates for local travel and freights than for through travel and freights. His bills, though unsuccessful, anticipated the legislation to which Congress has now resorted. Though himself not college bred, he was a warm friend of higher education. From 1869 to his death he was a member of the Corporation of Brown University. He founded the Hazard Chair of Physics with an endowment of forty thousand dollars.

He was a strong antislavery man, and took a somewhat active part in politics from the time of the organization of the Republican party. He was a delegate to the National Convention which nominated Fremont, and to subsequent Conventions.

He cherished a keen interest in questions of political economy and finance, and discussed them with great ability in newspapers and reviews. During the civil war he was frequently consulted on financial matters by Secretary Chase and President Lincoln. He made vigorous and successful efforts in Europe to promote the sale of the United States bonds, particularly in Holland and at Frankfort on the Main.

He is perhaps best known to the world by his philosophic writings. His earliest work, on Language, though showing some immaturity of thought, really contained the germs of the leading ideas in his subsequent philosophic discussions. It was published anony-

mously. It attracted the attention of Dr. Channing, who urged him to write a critical review of Edwards on the Will. For many years he pondered the problems of the will. In 1864 he published the book entitled "Freedom of Mind in Willing; or every Being that wills a Creative First Cause." It consists of two parts, the first setting forth his arguments for affirming the freedom of the will, and the second part being an answer to Edwards. He took the ground that all causation proceeds from the exercise of will, and that man is really a creative cause. During his visit to Europe, in 1864, Mr. Hazard met John Stuart Mill, and had much friendly discussion with him. From this grew his "Letters to Mill on Causation and on Freedom of the Mind in Willing" (1869). In 1883 he published his volume, "Man a Creative First Cause," which is a careful restatement and vindication of his philosophic ideas. It contains also a most interesting defence of the pursuit of metaphysical studies.

His philosophic writings recorded the unaided conclusions of his own mind. He read other philosophers but little. His mind was remarkably self-reliant and sure in its processes. He wrote with great vigor and clearness. It cannot be doubted that he would have been as eminent in mathematics, or perhaps in political economy, as he became in philosophy, had he given as much time to them as he did to philosophic thought. The high value of his philosophic writing has been widely recognized by the leading masters of philosophy here and in Great Britain. He presents in his life the rare example of a man crowded with a heavier pressure of business cares than most even of our active Americans carry, who yet found time, while travelling in stage-coaches, by rail, or on horseback, to produce works requiring the most abstract and concentrated thought on the profoundest themes which can engage the human mind.

He was a most attractive host, fond of congenial companions, and gifted in pleasant conversational discussions of the great subjects on which he has written. He enjoyed greatly the society of children; his heart was ever open with hospitality and charity to the needy, and he would spare no pains or expense to vindicate the humblest and poorest of his neighbors against wrong.

A complete edition of his works, edited by his granddaughter, Caroline Hazard, was published by Houghton, Mifflin, & Co. in 1889.

Mr. Hazard married Caroline Newbold of Bloomsdale, Pa., September 25, 1828. He died at his home in Peace Dale, June 24, 1888, twenty years after the decease of his wife. He left two sons, Rowland Hazard and John Newbold Hazard.

ALEXANDER JOHNSTON.*

The old adage that death loves a shining mark has seldom received a more sorrowful fulfilment than when, on the 20th of last July, Professor Alexander Johnston breathed his last. His death, although foreshadowed by a long period of illness and decline, caused a thrill of profound grief throughout the large circle of his acquaintance. Professor Johnston's connection with this College, although brief, had been sufficiently long to win for him a warm place in many hearts, and it is safe to say that no instructor has ever enjoyed in a larger measure the affection and esteem of his colleagues and pupils.

The facts of Professor Johnston's life are already well known. Born in Brooklyn in 1849, he spent the first twelve years of his life in that city, removing with his parents to Astoria, L. I., in 1861, where he studied for a short time in a public school, and completed his preparation for college under the tuition of a private tutor, Professor Alanson Palmer, of New York City. His father, who entered the army as a volunteer in 1861, returned in 1863, broken in health, and shortly after moved to Illinois, leaving young Alexander behind with Mr. John McAlan, his maternal uncle, under whose guardianship he completed his education. He entered Rutgers College as a Freshman in 1866, and after a brilliant and popular career, in which he became a recognized leader both in scholarship and athletics, and won several valuable prizes in college competitions, graduated in 1870 as first-honor man and valedictorian of his class.

Young Johnston, although an assiduous student and an omnivorous reader of books, had little of the bookworm in his composition. He was as fond of play as of work, and entered into the recreations of college life with a zest and energy which was only equalled by his devotion to his studies. It is said that he excelled in all the studies of the curriculum, being especially proficient in the classics, a taste for which he retained to the end of his life.

He returned to New Brunswick after graduation, and spent some time in post-graduate study and in teaching in the Grammar School; then entered the office of Ex-Governor Ludlow as a law student, and was admitted to practice at the New Jersey bar in 1876. Shortly after his admission to practice he left New Brunswick and went to Norwalk, Ct., where he married. In 1879, his first book, the "History of American Politics," appeared. In 1880 he started a school,

* By permission, from the Princeton College Bulletin, November, 1889.

to the management of which and to literary work he devoted his energies till the autumn of 1883, when he received a call to the Chair of Jurisprudence and Political Economy in this College. In January, 1884, he commenced his professorial duties, and his life from that time up to the day of his death was identified with Princeton, whose fame he was contributing to extend by his brilliant achievements as teacher and writer.

When it is remembered that Professor Johnston was barely forty years old when he died, and that his literary activity was crowded into the last ten years of his life, the list of works published during that period gives evidence of extraordinary fecundity. His "History of American Politics," published by the Holts in 1879, gave him at once a position in the front rank of American political writers. That book alone, had the author never written another word, was sufficient to make a great reputation. It is a fine embodiment of all the characteristic features of Professor Johnston's method and style. Clear, compact, straightforward, and simple, its mastery of facts and its generalizations are admirable, reminding one in these respects of Guizot's History of Civilization.

During his residence in Norwalk, Professor Johnston wrote the parts on American Political History in Lalor's Encyclopædia, his articles comprising perhaps one fourth of the contents of the three volumes, and being remarkable for the painstaking industry and accurate knowledge of facts which they evinced.

During his connection with Princeton there followed in rapid succession his School History; a collection of Representative Orations; the volume on "Connecticut" for the Commonwealth Series, a masterpiece of its kind; a number of articles in the American Supplement to the Encyclopædia Britannica; the splendid article, or rather treatise, on "The United States," in the ninth edition of the Encyclopædia Britannica; the strikingly able and original article on the American Constitution in the New Princeton Review; and many other articles in periodicals and reviews, besides frequent contributions to the "Topics of the Times" in the Century Magazine, and to the editorial departments of other publications. Besides the published works he left two books in manuscript form, which will in due time be given to the public.

Professor Johnston's later works fully sustain his reputation as a political writer. The qualities which are noticeable in his first volume are present in these, and there is evidence of a development in richness of knowledge, breadth of understanding, depth of insight, and

sobriety of judgment. The work on Connecticut is perhaps his masterpiece. It is a model of compact and lucid writing, and forcible and judicious thinking. It is more than a narrative, it is a piece of historical portraiture which presents the lineaments of a growing state.

In the strict sense of the term, Professor Johnston could not be called a philosophical thinker. To apprehend the underlying principles of things was not his forte, but rather to discover and formulate those middle axioms, to use a Baconian phrase, which are obtained directly by generalizations from experience. His mind also shunned abstractions, and theory had little attraction for him except so far as it could be found embodied in fact and experience. He was naturally averse to all *a priori* speculation, and found in history and its method the true basis for the science of politics. In his point of view he was a born jurist. The idea of positive law seemed to underlie and color his conceptions of every subject. This appeared most clearly in his method of dealing with the problems of political economy. That science may be considered in its relations with either ethics or jurisprudence. It was characteristic of Johnston to emphasize the latter, and one of the marked results of his teaching was the success with which he impressed his own mode of thinking upon the minds of his students.

As a teacher he had few equals. He succeeded, apparently with ease, in arousing and retaining the enthusiastic interest of his pupils, and his class-room with its throng of eager listeners had little in common with the traditional models of pedagogic dulness and formality. His success was due, in part, to his personality, which had in it something novel and refreshing, in part to his enthusiasm in his own work, and in large part, no doubt, to his method of presenting his subject. In his lectures he followed a concrete method, giving at the start a clear and concise definition of the principle involved, and then literally flooding it with a stream of pertinent and well selected illustrations. This latter was the most characteristic feature of his method. His faculty of teaching by example was extraordinary, and it was the wealth of illustration which he brought to bear upon a subject that revealed the extent and discriminating character of his reading, and the accuracy and power of his memory. Add to these qualities a never failing humor, and a genuine and hearty interest in the welfare of his pupils, and the strong hold which he invariably secured upon their interest and affection can readily be understood.

Professor Johnston carried into his general college relations the

same generous spirit that had characterized his own undergraduate life. In the professorial chair he still continued to believe in play as well as work and was an earnest and intelligent advocate of college sports. The students soon learned to trust him, and found in him not only a ready and generous sympathizer in all their affairs, but also an intelligent and judicious counsellor. He was thoroughly and consistently democratic in his ideas of college government, advocating on all occasions those old-fashioned ideas of personal freedom and personal responsibility, which he wished to see realized not only in the policy of the college, but also in the policy of the nation. To this end, his voice was always raised in behalf of what he deemed enlightened progress: the enlargement and development of the college curriculum, the removal of unnecessary restrictions, and the realization of the widest range of privilege consistent with the necessities of college discipline. To the consideration of practical affairs he brought to bear a clear and well trained intelligence, quick to realize the exigencies of any particular case and fertile in expedients to meet them.

The most attractive side of Professor Johnston's personality was reserved for those who were privileged to be his companions and friends. He was a brilliant conversationalist, possessed of a never failing fountain of wit and humor and an inexhaustible fund of anecdote, in the relation of which he displayed a unique power. It was a rare privilege to spend an hour with him when he was at his best. The recollection of many such comes back to memory as these lines are being penned, and causes a feeling of poignant regret that they shall recur no more, except in retrospect. None but those who enjoyed his friendship know what a genial soul the world has lost, and only they who knew the man as the central figure in the circle of his own home can appreciate the loss of the stricken family who mourn his untimely death.

The following is an approximately complete list of Professor Johnston's writings: —

1. History of American Politics, published in 1877 by Henry Holt & Co.
2. Political Articles in Lalor's Encyclopædia of Political Science. Published in Chicago, 1881.
3. Genesis of a New England State. In "Johns Hopkins Historical Studies." 1883.
4. Political Articles in the Supplement to the Encyclopædia Britannica. 1880.
5. Representative Orations. G. P. Putnam's Sons. 1884.
6. School History of the United States. Henry Holt & Co. 1885.

7. "Connecticut," for American Commonwealth Series. Houghton, Mifflin, & Co. 1887.

8. "The American Constitution," and other articles, for the New Princeton Review. July, 1888.

9. "The United States," in 9th edition of Encyclopædia Britannica. 1887.

Besides the following unpublished works: —

10. "The United States," taken from article in the Britannica.

11. Shorter History of the United States for Schools.

And in addition many articles, signed and unsigned, for the Century Magazine, the Nation, and other publications.

LEO LESQUEREUX.

Leo Lesquereux was born, November 18th, 1806, in the village of Fleurier, Neuchâtel. His father, a manufacturer of watch-springs, was descended from a Huguenot family which took refuge in Switzerland after the revocation of the Edict of Nantes. When a boy Lesquereux was of an adventurous spirit, and on one excursion fell from the edge of a high cliff, but almost miraculously escaped without permanent injury except a deafness which a few years later was intensified so that during the greater part of his life he could converse only with the greatest difficulty. He entered upon his academic studies in 1821, in a college of the town of Neuchâtel, and graduated with distinction in 1827. The slender means of his family forced him to support himself, in part, while a student, and after graduating he went to Eisenach, where he acted as tutor in a noble family. While at Eisenach he became engaged to a daughter of General Von Wolffskel, an *attaché* of the court of the Duke of Saxe-Weimar, to whom he was a short time afterwards married. In 1829 he returned to Switzerland, and became Principal of the College of La Chaux-de-Fonds in the Canton of Neuchâtel.

After his marriage, his deafness increased to such an extent as to unfit him for the profession of teacher, and, medical skill proving of no avail in his case, he was forced to gain a meagre living by engraving watch-cases, — a pitiable condition for one of his intelligence and education, who had only recently married a lady of noble birth. His health soon began to suffer, when his father offered to give him a share in his business, which, since it was on a small scale, did not improve his financial condition very much. He at this time began to devote his

few leisure hours to the study of plants, especially mosses, and, later, when a prize was offered by the government for the best essay on the formation and preservation of peat, he interested himself in making observations on this question, and competed successfully for the prize. In 1845 he was commissioned by the Prussian government to explore the peat-bogs of Northern Europe. But political complications now arose which affected the rest of his life. In 1848, the Canton of Neuchâtel, which had hitherto been under the dominion of Prussia, revolted, and joined the Swiss Federation. Lesquereux very naturally, considering the relations of his wife with the court of Saxe-Weimar, was a conservative, and, on the change of government, lost the position to which he had recently been appointed. In this emergency he was tempted to follow in the footsteps of his old schoolmate, Arnold Guyot, and his friend, Louis Agassiz; and, taking with him his wife and three children, he emigrated to America in 1848.

He went first to Cambridge, where he met his friend Agassiz, and obtained employment for a short time in assisting Asa Gray at the Herbarium. The botanist Sullivant, being in need of some one to aid him in his work on North American mosses, Lesquereux started for Columbus, Ohio, and became at once the assistant and intimate friend of Sullivant. He has left a most interesting account of his life at this period in a series of five letters, entitled "Lettres écrites d'Amérique," published in the "Revue Suisse" of Neuchâtel, 1849–50, in which he gave a full account of his own experience and impressions for the benefit of those who proposed emigrating to America, describing in a graphic way the trials of his family when crossing the ocean in the steerage, and the perplexities of a deaf man who could not speak English while travelling from Buffalo to Sandusky by boat on his way to Columbus. The letters are written in a charming style, with the vivacity almost peculiar to the French language, and they are full of amusing attempts to explain the incongruities of the American character as seen by a European, its seriousness and earnestness, on the one hand, contrasted with its disregard of social conventionalities and its political extravagances, on the other hand.

Lesquereux was fortunate in finding in Sullivant, not only a well informed botanist, but also a cultured gentleman of abundant means, which he was ready to spend in the advancement of his favorite studies. The two botanists worked harmoniously together until the death of Sullivant in 1873. Lesquereux was sent by Sullivant to collect mosses in the Southern States, and they together issued the first series of Musci Exsiccati in 1856, under the title of "Musci

Boreali-Americani." A second edition appeared in 1865. Lesquereux himself published comparatively little relating to mosses, although his first scientific paper was a "Catalogue of Mosses of Switzerland," published at Neuchâtel in 1840. H. N. Bolander, a resident of Columbus, had removed to California, and through this indefatigable collector Lesquereux received a large amount of new material from the West Coast, which he described in a paper "On California Mosses," in the Transactions of the American Philosophical Society, in 1863, and in a "Catalogue of the Pacific Coast Mosses," which formed the first Memoir of the California Academy of Sciences. In connection with Sullivant, he contributed to the Proceedings of our Academy in 1859 an account of mosses collected by Charles Wright during the North Pacific expedition under Commodore John Rodgers.

An account of the Musci and Hepaticæ of the United States east of the Mississippi River had been prepared by Sullivant in 1856, for the second edition of Gray's Manual, and at the time of his death he was engaged with Lesquereux in preparing a Manual of the Mosses of North America. Excessive use of the microscope having impaired Lesquereux's sight, after Sullivant's death he called Mr. T. P. James of Cambridge to his assistance in completing the Manual. The work was advancing slowly when James died suddenly in 1882, and Sereno Watson then undertook the difficult task of putting the whole material into proper shape, and it was finally given to the public in 1884.

Although, by a fortunate chance, Lesquereux was able almost immediately on his arrival in America to turn to good account the knowledge of mosses acquired while he was in Europe, and although he was recognized in later years as, after Sullivant, the leading bryologist of America, it is chiefly to his knowledge of fossil plants that his high position among American scientific men is due. In the field of vegetable palæontology he unquestionably stood at the head in America. His early studies on the origin of peat first introduced him to the scientific circles of Europe, and were the means of securing for him the friendship of Louis Agassiz, a friendship which strengthened as years passed on. The vast unexplored treasures of plants buried in the coal measures were very imperfectly known when Lesquereux arrived in America. He gradually began the study of those forms which were at hand, and as the different States developed their geological surveys material accumulated in vast quantities, and Lesquereux was soon recognized as the one best fitted to prepare reports on the

fossil plants. The material thus amassed was elaborated slowly and cautiously, and with the maturity of years resulted in an astonishing number of volumes, which towards the close of his life followed one another in rapid succession, and we are told that there are still other volumes awaiting publication.

His first paper on fossil plants of America was apparently the one entitled "New Species of Fossil Plants," in the Boston Journal of Natural History of 1854, and there soon followed reports on the fossil plants in the Geological Surveys of Pennsylvania and Kentucky (1857), and later in the Surveys of Indiana, Illinois, and Arkansas, and the National Surveys of the different Territories. Work on mosses was gradually abandoned, as the work on fossil plants became more and more absorbing. In the opinion of experts his most important contribution to palæontology was "Description of the Coal Flora of the Carboniferous Formation in Pennsylvania," in the Second Geological Survey of that State. It appeared in 1880, and showed to what a remarkable extent he had retained his mental vigor unimpaired, notwithstanding his infirmity and the hardships to which he was subjected until he reached middle life. His palæontological work was largely descriptive, and the number of new species of which he was sponsor is very great. But in the long list of his published works are to be found a considerable number in which he treated his subject in a general and philosophical way. Although his investigations were by no means limited to the coal measures, it is fair to say that his writings show a preponderance of those in which he either described plants from the coal formations or discussed in a general way the origin of coal and the accompanying and resulting phenomena. His early observations at Neuchâtel had made him intimately acquainted with the conditions under which, at the present day, peat is formed, and the surmise of Brongniart, that in past ages coal might have been formed under similar conditions, turned out to be in the reflecting mind of Lesquereux a suggestion rich in practical results as well as in theoretical speculations. Lesquereux was not the author of any works intended primarily for instruction, although his paper on "Principles of Palæozoic Botany," in the Geological Report of Indiana of 1884, might well be called an educational treatise.

In Lesquereux we have a remarkable instance in which intelligence and industry succeeded in overcoming both physical infirmity and depressing surroundings. Although during his long scientific career he was never able to take part in conversation, he was free from the moroseness often found in the deaf, and, on the contrary,

was genial and companionable. He had reached middle life before he was freed from the load which poverty imposes on one who has a family to support, but, struggling along as best he could, he made himself a leader among scientific men. His gentle manner and delicacy of feeling, joined with a cheerful, even sprightly disposition, made him beloved by his associates and the friend even of those who differed with him in opinion. Few have been permitted to enjoy so many years of unremitting mental activity. Lesquereux was over eighty before the warning came that his work must be relaxed. Two years before his death he suffered a stroke of paralysis, and he grew gradually more and more feeble, until he died at his home in Columbus, October 25, 1889, nearly eighty-three years old.

ELIAS LOOMIS.

Elias Loomis was born in Willington, Connecticut, on August 7, 1811. His father, the Rev. Hubbell Loomis, was pastor in that country parish from 1804 to 1828. He was a man possessed of considerable scholarship, of positive convictions, and of a willingness to follow at all hazards wherever truth and duty, as he conceived them, might lead.

Although the boy inherited from his father a mathematical taste, yet his love for the languages also was shown at a very early age. At an age when many bright boys are still struggling with the reading of English, he is reported to have been reading with ease the New Testament in the original Greek. He prepared for college almost entirely under the instruction of his father. At the age of fourteen he was examined and was admitted to Yale College, but owing to feeble health he waited another year before actually entering a class. In college he appears to have been about equally proficient in all of the studies, taking a good rank as a scholar, and maintaining that rank through his college course. He graduated in 1830.

The next year was spent in teaching. In 1831 he entered the Andover Theological Seminary with the expectation of becoming a preacher. This purpose was, however, changed, when a year later he was appointed Tutor in Yale College. Here he remained for three years and one term. In the spring of 1836 he received the appointment to the Chair of Mathematics and Natural Philosophy in Western Reserve College, at Hudson, Ohio. He was allowed to spend the first year in Europe. He was, therefore, during the larger part of the year 1836–37, in Paris, attending the lectures of Biot, Poisson, Arago,

Dulong, Pouillet, and others. In the autumn of 1837 he began his labors at Hudson. Here he remained for seven years, maintaining with unflagging perseverance both his work in teaching and his scientific labors.

In 1844 he was offered, and he accepted, the office of Professor of Mathematics and Natural Philosophy in the University of New York.

When Professor Henry resigned his professorship at Princeton in order to accept the office of Secretary of the Smithsonian Institution, Professor Loomis was offered the vacant chair. He went to Princeton and remained there one year, at the end of which he was induced to return again to New York. Here he continued until 1860, when he was elected to the professorship in Yale College made vacant by the death of Professor Olmsted. For the last twenty-nine years of his life he there labored for the College and for science, passing away on the 15th of August, 1889.

There are three or four lines of the scientific activity of our late Associate sufficiently distinct to be considered separately, without strict regard to chronology.

Terrestrial Magnetism and the Aurora. — A subject of which he early undertook the investigation was Terrestrial Magnetism. The daily motions of the magnetic needle were those which Tutor Loomis first studied. At the beginning of the second year of his tutorship, he set up by the north window of his college room a heavy wooden block, and on it the variation compass belonging to the College. Here for thirteen months he observed the position of the needle at hourly intervals in the daytime, his observations usually being for seventeen successive hours of each day. The results of these observations, together with a special discussion of the extraordinary cases of disturbance, were published in the American Journal of Science in 1836. No similar observations of the kind made in this country had at that time been published, and it is believed that there are only one or two like series of hourly observations made in Europe earlier than these by Tutor Loomis. He also at this time formed the purpose of collecting all the observations of magnetic declination that had hitherto been made in the United States. From these he constructed a magnetic chart of the country. These were the first published magnetic charts of the United States. In the following years he made numerous observations of the magnetic dip at widely distributed stations in the United States, — observations which are of great value in present discussions of the changes of the magnetic elements.

Closely connected with terrestrial magnetism, and to be considered

with it, is the *Aurora Borealis.* Observations and discussions of an exceedingly brilliant display of Northern Lights, which occurred in 1859, were given to the public by Professor Loomis during the following two years, in a series of nine papers in the American Journal of Science. In 1870 he published a paper of importance relating to terrestrial magnetism, in which he showed its connection and that of the aurora with spots on the sun. A further discussion of the periodicity of the auroras was undertaken by Professor Loomis, and published in 1873.

Astronomy. — Another important line of Professor Loomis's work was Practical Astronomy. While in Europe in 1836–37 he bought for Western Reserve College the instruments for an observatory. These were a four-inch equatorial, a transit instrument, and an astronomical clock. On his return he erected, in 1837, a small observatory at Hudson, and in September, 1838, began to use the instruments. It may not seem a very large output of work in six years' time to have determined the location of the observatory, and to have observed five comets. But we must remember that the telegraph had not then been invented, that the exact determination of the longitude of a single point in the Western country had a higher value then than it can have now, and that it could be obtained only by slow and tedious methods. These were moreover, days of small things in astronomy in this country. At Yale College there was a telescope, but not an observatory. At Williamstown an observatory had been constructed, but it was used for instruction, not for original work. At Washington Lieutenant Gilliss, and at Dorchester Mr. Bond, were commissioned by the government in 1838 to observe moon culminations, in correspondence with the observers in the Wilkes Exploring Expedition, for determining their longitude. These two prospective sets of observations, both of them under government auspices and pay, were the only signs of systematic astronomical activity in the United States outside of Hudson, when in 1838 Professor Loomis began his observing there.

In the summer of 1844, a new method in astronomy had its beginnings. The telegraph line had just been built between Baltimore and Washington, and Captain Wilkes at Baltimore compared his chronometer by telegraph with one at Washington, and so determined the difference of longitude of the two places. This method was immediately utilized by Professor Bache in the Coast Survey, and for three seasons Professor Loomis aided Mr. Walker in developing the new method, and making it practically useful.

Meteorology. — The science of Meteorology is, however, that in which Professor Loomis has made the most important contributions to human knowledge. From the date of his tutorship at Yale, Professor Loomis had taken a warm interest in meteorology; and in particular its central problem, the theory of storms, held in his thought and work the first place from that time to the day of his death. For several years, in Hudson, he steadily performed the naturally irksome task of making twice each day a complete set of meteorological observations. He also undertook the discussion of several large storms. A paper giving the results of the discussion of two of these storms, occurring in the month of February, 1842, was sent to Professor Bache, and read by him at the centennial meeting of the American Philosophical Society in May, 1843, and created, as Professor Bache wrote, a great sensation. It was at that time important for the light which it threw upon the rival contending theories of Espy and of Redfield, but it was more important by far by reason of the new method of investigation then for the first time employed. In this discussion of the storms of 1842, Professor Loomis drew on the map a series of lines of equal barometric pressure, or rather of equal deviation from the normal average pressure for each place. A series of maps representing the storm at successive intervals of twelve hours were thus constructed, upon each of which was drawn a line through all the places where the barometer stood at its normal or average height. A second line was drawn through all the places where the barometer stood $\frac{2}{10}$ of an inch below the normal; and other lines through points where the barometer was $\frac{4}{10}$ below, $\frac{6}{10}$ below, $\frac{8}{10}$ below, etc.; also lines were drawn through those points where the barometer stood $\frac{2}{10}$, $\frac{4}{10}$, $\frac{6}{10}$, etc., above its normal height. The deviations of the barometric pressure from the normal were thus made prominent, and all other phenomena of the storm were regarded as related to those barometric lines. A series of colors represented respectively the places where the sky was clear, where the sky was overcast, and where rain or snow was falling. A series of lines represented the places at which the temperature was at the normal, or was 10, 20, or 30 degrees above the normal or below the normal. Arrows of proper direction and length represented the direction and the intensity of the wind at the different stations. These successive maps for three or four days of the storm furnished to the eye all its phenomena in a simple and most effective manner. The method seems so natural, that it should occur to any person who has the subject of a storm under consideration. But the greatest inventions are oftentimes the simplest, and the

invention and introduction of this method of representing and discussing the phenomena of a storm was probably the greatest of the services which Professor Loomis rendered to science. This method is at the foundation of what is sometimes called "the new meteorology," and the paper which contains its first presentation is perhaps the most important paper in the history of that science.

At the close of this memoir Professor Loomis warmly urged the plan of a systematic meteorological campaign. Shortly afterwards this Academy appointed a committee, of which Professor Loomis was chairman, to urge upon the proper authorities the execution of the plan. The American Philosophical Society of Philadelphia united its voice with that of the Academy. About this time Professor Henry was made Secretary of the Smithsonian Institution, and he determined to make American meteorology one of the leading subjects of investigation to be aided by the Institution. At Professor Henry's request, Professor Loomis prepared a report upon the meteorology of the United States, in which he showed what advantages society might expect from the study of the phenomena of storms; what had been done in this country toward making the necessary observations, and toward deducing from them general laws; and, finally, what encouragement there was to a further prosecution of the same researches. He then presented in detail a practicable plan for securing the hoped for advantages in their fullest extent.

The scheme laid down by Professor Loomis was in part followed out by the Institution. But the fragmentary character of the observations, the want of systematic distribution of the observers, and the imperfections of the barometers, made the material collected difficult of discussion. Professor Loomis waited in hopes of some better system.

This better system came when the United States Signal Service was established, in 1871. The daily maps of the weather published by the Bureau were constructed essentially after the plan which Professor Loomis had, thirty years before, invented for the treatment of the storms of 1842. As soon as these maps had been published for the two years 1872 and 1873, Professor Loomis commenced in earnest to deduce from them the lessons which they taught us respecting the nature and the phenomena of United States storms. To this investigation he gave nearly all his energies during the remaining fifteen years of his life. Beginning in April, 1874, he presented at each of eighteen successive meetings of the National Academy of Sciences, in April and in October of each year, a paper entitled "Contributions to Me-

teorology." These were at first based upon the publications of the Signal Service alone; but, as years went by, like publications appeared in Europe that were useful for his work. These papers were published in July and January following the Academy meeting, and they regularly formed the first and leading article in eighteen successive volumes of the "American Journal of Science." Gradually, one after another of his college duties was committed to others, that he might give his whole strength to these investigations. In 1884 he began a revision of the whole series of papers. They had been presented without much regard to systematic order in the subjects investigated, and new material had accumulated from time to time, so that a thorough systematic revision seemed absolutely necessary.

In 1885 he presented to the National Academy of Sciences the first chapter of this revision, in which he discussed the areas of low pressure, their form, their size, their motions, and the phenomena attending them. Two years later, in 1887, the second chapter of the revision appeared, in which he discussed the areas of high pressure, their form, magnitude, direction, and velocity of movement, and their relation to areas of low pressure. Gradually his physical strength was failing, though his mind was bright and clear as ever. To this work — the only work which he was now doing — he was able to give two or three hours a day. Anxiously he husbanded his strength, slowly and painfully preparing the diagrams and the tables for the third chapter upon rain areas, the phenomena of rainfall in its connection with areas of low pressure, and the varied phenomena of unusual rainfall. "I see," he said to a friend, "not the end of this subject, but where I must stop. I hope I shall have strength to finish this work, and then I shall be ready to die."

This third and finishing chapter was finally passed through the printer's hands, and some advance copies distributed to correspondents abroad, in the summer months of 1889. His work upon the theory of storms he felt was finished. Before the close of the vacation he died.

These three chapters of his revised edition of "Contributions to Meteorology" constitute the full and ripe fruitage of his work in his favorite science. They will for a long time to come be the basis of facts by which writers in theoretical meteorology must test their formulas. They cover all the important points taken up in the twenty-three earlier memoirs, with one important exception, the relation of mountain observations to those made on the plains below.

Professor Loomis became interested in the subject of genealogy early in life, and that interest remained unbroken to his last days.

He published three large volumes, giving the names, residences, etc. of about twenty-seven thousand descendants of his ancestor, Joseph Loomis, who came from England to this country in 1638.

Professor Loomis was doubtless more widely known as the author of mathematical text-books than as a worker in new fields of science. Shortly after coming to New York, he prepared a text-book in Algebra. The market was ready for a good book of this kind, and the work prepared for it was a good one. Other books followed the Algebra from year to year, the whole forming a connected series from Arithmetic upward, so that the list of his works finally numbered near twenty volumes. His experience in teaching, his rare skill in language, his clear conception of what was important, and his unwearied painstaking, combined to produce text-books which met the wants of teachers. About six hundred thousand volumes have been sold, benefiting the schools and colleges, and bringing to the author a liberal and well merited pecuniary return.

College graduates who have been under his instruction will probably retain a more positive impression of the personal traits and the character of Professor Loomis than of most of their other teachers. His crisp sentences, lucid thought, exactness of language, and steadiness of requirement, more than made up for any apparent coldness and real reserve. "If I have been successful in life," said Chief Justice Waite (a member of the Yale College class of 1837), "I owe that success to the influence of Tutor Loomis more than to any other cause whatever." Professor Loomis lived a somewhat isolated life, especially in his later years, but there was in him no trace of selfish or morbid feeling. In council his advice was always marked by his clear judgment of what was important, and at the same time what was practicable.

After going to New York he had a generous income from his books, besides his salary as Professor. The amount he saved from his income was carefully and prudently invested, and before his death the savings with their accumulations were a large estate, — how large only he and his banker knew. After making liberal provision for his two sons, he bequeathed his estate to the Astronomical Observatory of Yale University. The income from more than three hundred thousand dollars will eventually be available to continue the work of his life.

MARIA MITCHELL.

MARIA MITCHELL was born at Nantucket, Mass., August 1, 1818; she was the third child of William and Lydia C. Mitchell, her mother's maiden name having been Coleman. They were birthright members of the Society of Friends, and descended from such on both sides for several generations. Maria may well have inherited a taste and disposition for learning from a people whose fundamental "Discipline" as far back as 1695 included the equal education of both sexes and all classes. In 1737 it was "advised that Friends should instruct their children in French, High and Low Dutch, and Danish"; but this amendment to the "Discipline" (of English origin) was not suited to the wants of islanders far off in the Western Ocean; and so it came to pass that the Nantucket Quakers substituted for these languages some rudiments of the sciences, especially those related to navigation.

At the beginning of this century the Nantucket whalers ventured around Cape Horn, and stood out across the lonely Pacific Ocean, where every refinement of skill and intelligence in observations of the heavenly bodies was brought into requisition to trace their courses over vast regions never before traversed. The study of navigation became therefore the highest ambition of the Nantucket boy; and since this science involves mathematics and astronomy, it was broad enough to interest the other sex beyond the mere sympathy of common interests; and thus arose in this isolated community an intellectual excitement, the antithesis of its monotonous and repressive religious system. Maria's mother used to tell how in her infancy the little children were already taught to box the compass in the "Monthly Meeting School" in place of the Catechism; and her father boasted that in the short period of his direction of the Howard Street School he graduated two girls — one of whom was Maria's elder sister Sally — who made "graphical predictions" of the eclipse of 1831, then near at hand.

It was this annular eclipse, described in the next year's American Almanac as a "splendid spectacle," — "beautiful and sublime," — that first called in the services of Maria Mitchell, as appears from the accompanying fac-simile of her father's observations at Vestal Street.

We conjecture that the note signed "M. M." was added after her father's death, in 1869, at the time his papers were gathered up.

Professor Mary W. Whitney, the able associate and successor of Miss Mitchell at Vassar College, informs us that "the third return of the

Wm. Mitchell

Eclipse of 2 mo 1831

Time by clock Beginning — —	11··58" 14
Formation of ring	1 · 29 · 35
Rupture of ring	1 · 31 · 17
End of the Eclipse	2 · 55 · 42
Duration of ring	1 · 42
Duration — —	—

Clock too fast - 3′ 7″

Mean — Time — corrected

	h ′ ″
Beginning —	11 · 55 · 07
Formation of ring	1 · 26 · 28
Rupture of ring	1 · 28 · 10
End of eclipse	2 · 52 · 35
Duration of ring — — —	1 · 42
Duration of Eclipse	2 ·· 57 · 28

12
11 · 55 · 07
· 04 · 53
2 · 52 · 35
2 · 57 ·· 28

This time was noted by me;
I was 12½ years old. M. M.

eclipse, corresponding to this one during which she noted the time for her father, occurred fifty-four years later, and at that time she again sat by the chronometer and noted the seconds of beginning and end, as she had done for her father, now for her pupils."

These observations of the eclipse, made in concurrence with those of Paine at Monomoy and Bond at Dorchester, had for practical object the determination of the longitude of the house in Vestal Street where the chronometers of the whale-ships were carried to be rated and set to Greenwich time. Mr. Mitchell came in time to be the rater of all the chronometers of a fleet of ninety-two whale-ships, requiring observations on every fine day of the year. We mention this to indicate how accustomed his daughter must have been to the talk of astronomy, even as the source, in part, of her daily bread.

As Halley's Comet approached, in 1835, there was much anxiety to be foremost in the rediscovery. From Mr. Mitchell's note-books it would seem that it was first seen at Yale College, and next at Nantucket, while it was yet a very faint telescopic object. His daughter Maria, remembering all the excitement, never relinquished her father's claim to priority, as indicated by a note made by her on the margin of his journal not long before her death. "He [her father] was one of the first, if not the very first, to see Halley's Comet on its return in 1835. — M. M." Coming so near to priority served, as it proved, to give to the Vestal Street lookout the rank of an observatory, and introduced to the family valuable acquaintances among the rising astronomers.

At the time she assisted at the eclipse, Maria attended her father's school, and several of his pupils still live at Nantucket to bear witness to the enthusiasm which his teaching usually excited; but it was not till she was a pupil of Cyrus Peirce that she began to study in earnest. Father Peirce (as he was called many years later when he came to be the Principal of the first Normal School) had a natural genius for teaching, and a great many accomplished women now living found their earliest inspiration in his school. Maria remained with him two years, one as pupil and one as assistant teacher, and there began her mathematics and also began to develop that power of concentration of mind for which she became remarkable in later years.

The books in which her earliest notes appear are Bridge's "Conic Sections," Hutton's "Mathematics," and Bowditch's "Navigator." Some of the notices have spoken of her as backward in childhood upon her own authority; but the date of her review of the "Hyperbola" in Hutton is given on the margin, and makes her seventeen,

which shows that by that time she had caught up to or passed her contemporaries. She was not yet twenty when an effort was made to induce her to open a school for navigation. She declined, but whether constrained by her own fears or those of the underwriters we are not advised.

The "Navigator," or, as the whalers were prone to call it, the "Epitome," was the text-book of all the young men fitting to be whalers; but it was quite out of the question for any of these to comprehend the mathematics that lay hidden behind the practical formulas of navigation, Maria Mitchell, however, was not content with the letter, and undertook to reach the spirit of Bowditch's precepts. This was not an easy task in those days, before Professor Benjamin Peirce had published his "Explanation of the Navigator and Almanac," and she was obliged to consult many different scientific books and the reports of mathematical societies before she could herself construct the astronomical tables.

In 1836, her father became Cashier of the Pacific Bank and the family moved into the bank building on Main Street. The next year she was appointed Librarian of the Nantucket Athenæum, a position which she held for seventeen years. The library was open to the public only a few hours of each day, so that she had great opportunity for reading and study, with the best authorities in literature and science within reach. This library was destroyed by fire in 1846; but the disaster created so much interest in other portions of New England that means were soon supplied for building it up again, and the library to-day is really a better one than it ever was before, although it possesses fewer curious and original editions of old authors than formerly.

It was in this library that Miss Mitchell found Laplace and made a special study of Bowditch's Appendix to the third volume of the "Mécanique Céleste," which treats of the orbits of comets; and here, too, she read the "Theoria Motus" of Gauss in its original Latin form. This was at a progressive period in her father's scientific career, and his daughter contributed to his success by the most devoted assistance. She helped in the observations at all hours of the day or night that became necessary, and when her father was absent on lecturing or business tours she maintained the continuity of series of observations that he had undertaken. These two enthusiasts acquired gradually quite a well equipped observatory. Mr. Mitchell purchased an excellent telescope and a large celestial globe; many instruments were also loaned to him under obligations to supply data

for State or Government surveys. The State lent a transit for the meridian, West Point Academy sent a repeating circle, and the Coast Survey furnished an equatorial telescope and a transit instrument for the prime vertical, *the understanding being that the observatory at Nantucket should be one end of a great arc in the determination of the figure of the earth.*

Mr. Mitchell had enjoyed in his youth an acquaintance with many of the students of astronomy, and this acquaintance extended as the theme became more and more popular in our country. The observatory at Nantucket had the advantage, therefore, of personal visits from kindred spirits of the outside world; and as at this period Mr. Mitchell was appointed one of the Overseers of Harvard College and placed on the Observatory Committee (a portion of the time as Chairman), the little observatory at Nantucket was brought into intimate relations with the best of its kind in the country.

For several years father and daughter worked together on routine observations of the cumulative sort, much relied upon in those days as cancelling errors which modern improvements in instruments and methods have more effectually corrected. They observed moon culminations and occultations for longitude, and the transit of stars across the prime vertical for latitude, until, towards the last, they obtained a zenith telescope. The aspects of the planets, the solar spots, meteors, and auroral clouds, were observed diligently. But in 1845, when Smyth's "Celestial Cycle" (containing the Bedford Catalogue) appeared, they entered upon systematic studies of nebulæ and double stars, using often the two telescopes side by side on the top of the Pacific Bank. Thenceforth they were prospectors beyond the frontiers; and routine work gave place to exciting explorations.

Many years after these explorations began, Miss Mitchell being a guest at St. John's Lodge, was asked by Admiral Smyth if his book had reached as far as Nantucket. She replied, "If it is a fine night at Nantucket, my father has your catalogue open upon the table, and runs in every few minutes from his telescope to identify his objects." The Admiral expressed his gratification at this homage, but remarked that his "forte" was poetry; and he gave her some verses printed upon a little press by himself, because, as he facetiously remarked, "*the publisher could not appreciate their merits.*" Those who are familiar with the Bedford Catalogue will remember "certain Brackish lines" and "Galley rhymes" mingling strangely with classical quotations. Miss Mitchell was lenient towards this kind of simplicity; she too had been prone to repeat verses, and even to compose very good

ones, as she awaited the transit of stars, *but she did not print them with her reports.*

Sweeping the heavens with the telescope through the long hours every clear night, as Miss Mitchell was wont to do, means healthy courage and hopes that prophesy success. A great many times she was deceived by the changes in the aspect even of familiar objects, and made measures in vain; but several new nebulous spots served to keep up her enthusiasm, and the discovery of three comets, not quite in time, but in advance of their announcements, excited expectation. Fortune favors the faithful; and in the autumn of 1847, a brand-new object entered the field of her telescope and was immediately "determined" in position. This object, being again observed on the following night, was found to be in motion among the stars, and, as it proved, was a comet not yet seen in any other part of the world.

In 1831, the same year that Maria Mitchell entered her astronomical apprenticeship as time-keeper at the "sublime" eclipse, Frederic VI., King of Denmark, at the suggestion of Professor Schumacher of Altona, founded a "gold medal of the value of twenty ducats to any person who should first discover a telescopic comet." This medal was awarded to Miss Mitchell, after considerable correspondence, conducted mainly by Hon. Edward Everett, whose "Introductory Note" to the letters, as finally compiled, reads as follows: —

"On the 1st of October, 1847, at half past ten o'clock, P. M., a telescopic comet was discovered by Miss Maria Mitchell of Nantucket, nearly vertical above Polaris about five degrees. The farther progress and history of the discovery will sufficiently appear from the following correspondence. On the 3d of October the same comet was seen at half-past seven, P. M., at Rome, by Father de Vico, and information of the fact was immediately communicated by him to Professor Schumacher at Altona. On the 7th of October, at twenty minutes past nine, P. M., it was observed by Mr. W. R. Dawes, at Camden Lodge, Cranbrook, Kent, in England, and on the 11th it was seen by Madame Rümker, the wife of the Director of the Observatory at Hamburg. Mr. Schumacher in announcing this last discovery observes, 'Madam Rümker has for several years been on the lookout for comets, and her persevering industry seemed at last about to be rewarded, when a letter was received from Father de Vico, addressed to the editor of this journal, from which it appeared that the same comet had been observed by him on the 3d instant at Rome.'

"Not deeming it probable that his daughter had anticipated the

observers of this country and Europe in the discovery of this comet, no steps were taken by Mr. Mitchell with a view to obtaining the King of Denmark's medal. Prompt information, however, of the discovery was transmitted by Mr. Mitchell to his friend, William C. Bond, Esq., Director of the Observatory at Cambridge. The observations of the Messrs. Bond upon the comet commenced on the 7th of October; and on the 30th were transmitted by me to Mr. Schumacher, for publication in the *Astronomische Nachrichten.* It was stated in the memorandum of the Messrs. Bond, that the comet was seen by Miss Mitchell on the 1st instant. This notice appeared in the *Nachrichten* of December 9, 1847, and the priority of Miss Mitchell's discovery was immediately admitted throughout Europe. . . .

"Mr. Fleniken entered with great zeal and interest into the subject. He lost no time in bringing it before the Danish government, by means of a letter to the Count de Knuth, the Minister at that time for Foreign Affairs, and of another to the King of Denmark himself. His Majesty, with the most obliging promptness, ordered a reference of the case to Professor Schumacher, with directions to report thereon without delay. Mr. Schumacher had been for a long time in the possession of the documents establishing Miss Mitchell's priority, which was indeed admitted throughout scientific Europe. Professor Schumacher immmediately made his report in favor of granting the medal to Miss Mitchell, and this report was accepted by the King. The result was forthwith communicated by the Count de Knuth to Mr. Fleniken, with the gratifying intelligence that the King had ordered the medal to be awarded to Miss Mitchell, and that it would be delivered to him for transmission as soon as it could be struck off. This has since been done."

Among those who most promptly became Miss Mitchell's champions in this claim made for her by friends was Admiral Smyth, the same who had been her guide through the Celestial Cycle. Professor Schumacher, who had suggested the foundation of the medal, was also active in her behalf, and Madame Rümker sent congratulations. It seems probable that Miss Mitchell's failure to make any claim for herself, and the voluntary appearance of several distinguished champions, attracted the attention of European astronomers to the peculiar merits of the case. It was found that she was not only fully able to make all the observations and computations required for locating celestial objects, but that she could compute their orbits and predict their reappearance in our skies. The European astronomers came to feel a personal interest in her; and when, some years later, she

crossed the ocean, she became the honored guest of the most learned men in Europe, and visited all the observatories as a privileged inspector of their instruments and methods.

In Professor Joseph Henry's Report to the Regents of the Smithsonian Institution for the year 1849, we find the following in his review of communications: "The next memoir is an account of the discovery of a comet by Miss Maria Mitchell of Nantucket, with its approximate orbit, calculated by herself. The honor of this discovery has been duly awarded to the author. A gold medal has been awarded to her by the King of Denmark, and the comet is now known by her name to astronomers in every part of the world. From the peculiarities of the case the Executive Committee recommend that a small premium be presented to Miss Mitchell." This recommendation was adopted.

We have thought it only just to quote directly from the highest contemporaneous authorities concerning the importance of scientific work done a half-century ago, because the rapid progress of later years makes us liable, in retrospect, to look through the wrong end of the telescope.

On the 30th of May, 1848, Miss Mitchell was elected to the American Academy of Arts and Sciences, "unanimously," although she was the first and the only woman ever admitted. There is a tradition of the Academy, that at her election a serious discussion arose as to the propriety of calling her a *Fellow;* and in the diploma the printed word "FELLOW" is erased, and the words "Honorary Member" are inserted by Dr. Asa Gray, who signs the document as President. Some years later, however, we find her name in the list of Fellows of this Academy, of the American Institute, and of the American Association.

In the summer of 1849 she accepted an invitation from Professor Bache, then Superintendent of the United States Coast Survey, to take service in the astronomical party at Mount Independence, Maine, and as the guest of his family. This was a station in the chain of primary triangulation, and it lay so near the meridian of her observatory that it could be used in the measure of the proposed great arc extending northward from Nantucket. In the same year she was appointed one of the computers of the Nautical Almanac, receiving her initiative from Professor Benjamin Peirce. This office she held for nineteen years, and was mostly employed upon "Part II. The Astronomical Ephemeris for the Meridian of Washington," — the planet Venus being her particular assignment.

In the education of a pupil, the daughter of a Western banker, she was enabled to make a journey through the United States in 1853, and sailed for Europe the same year. This was her first going abroad, and friends on both sides of the water were determined that one so earnest and appreciative should have every opportunity the world could afford. She went accredited to distinguished women, as well as to distinguished men. She visited the great astronomers, not only at their observatories, but at their homes, and discovered a likeness among this sort of people everywhere, — a likeness that lay in the simplicity of their domestic lives, and in their elevation of thought. In short, she found what she went to seek, and what she went to carry, an appreciative sympathy.

It was in the course of this journey that she made an *inspection* of the Roman Observatory under a special dispensation which had been denied to others of her sex, including Mrs. Somerville and the daughter of Sir John Herschel. Soon after, she was made the recipient of the bronze medal of merit from the Republic of San Marino, together with the "Ribbon" and "Letters Patent" signed by the two Captains Regent. Some of the notes of this first European journey appear in the Atlantic Monthly, under the title of "A Visit to Mary Somerville," and others were published after her death in the Century Magazine, under the title of "Maria Mitchell's Reminiscences of the Herschels." On her return home from this journey, she received an excellent equatorial telescope, made by Alvan Clarke, and presented by Miss Elizabeth Peabody, "representing the women of America."

The years between 1857 and 1860 were the saddest of her life, and the most valuable in her manner of computing time; for these were years of watching and nursing the declining strength of her mother. She was alone with her parents, her sisters having married. This mother — who had formerly, in the midst of her large family, been a strong and steady principle, the source of its ambitious spirit, and the object of an affection that bound the children together as in a common cause — now gradually sank away, mind and body together, till her death took nothing out of the world except a precious and painful duty.

We ought perhaps to mention that Miss Mitchell's mother had been, for a brief period before her marriage, a teacher, as her mother before her had been. The only other in any sense *public* duty that had devolved upon her was, in later years, that of presiding "Clerk" of the Nantucket Monthly Meeting of Friends.

Miss Mitchell resigned her place in the Nantucket Athenæum in 1853, and after her mother's death, in 1861, she and her father moved from Nantucket to Lynn, where her sister was already settled, and where she was able to make a home for her father, now retired from business. She always spoke of this period of her life as dull and arid. She had lost a very dear occupation at the death of her mother, and for a while her enthusiasm for her scientific work seemed likely to give way. She was perhaps quite ready for a change in the routine of her life, when the opportunity for change offered itself.

In the year 1865 she was appointed Professor of Astronomy and Director of the Observatory at Vassar College. Although she had been consulted somewhat in the equipment of the observatory, the building was not what, in her mind, it should have been for the money expended, and she discovered in course of time that the serious tone of an institution of high learning had not been anticipated in its construction. It must be said, however, that the founder, Mr. Vassar, stood by her in every determined step that she took, and the very appreciative and far-sighted President, Dr. Raymond, satisfied the Trustees that the credit of the institution and its real usefulness could be guaranteed only by establishing its claims to scientific recognition, and that to this end the requirements necessary to admission to the observatory must be severe. And so it came to pass that Professor Mitchell's classes were small, and that from the outset a rigorous mathematical training accompanied the course, beyond the usual limits. Professor Whitney says: "The struggle between the desire to establish and maintain a truly collegiate standard, and the necessity of securing a sufficient number of pupils to meet the yearly expenses of the institution, began with the life of the College. That incubus upon college progress, a preparatory course school within its own walls, could not then be avoided. But I am happy to say that it has now passed out of existence."

Miss Mitchell's studies were not relinquished during these years of teaching, for she had a happy faculty of taking her pupils with her explaining to them abstruse points, and making them companions in the labor and the harvest; still, as Miss Whitney observes, — "It is possible that, had she determined to remain only an observer, she might have contributed more to the stock of astronomical knowledge, since the daily routine of class preparation and class work must very essentially curtail the night work of an astronomer. But," she continues, "I must believe that her choice was the wise one, and that what Vassar College has gained, and all the young women have gained

who have come under her influence, must far outweigh the possible increase in astronomical fact that might have followed from these twenty-three years, if devoted exclusively to the work of the telescope. Her interest in the physical peculiarities of the larger planets determined the lines of her observation at Vassar. Jupiter and Saturn were her favorite study. She published several papers on these planets, some printed in Silliman's Journal and some at her private expense. When photography became an important agent in the study of the solar surface, she constructed at her own cost the necessary apparatus for photographing the sun, and placed in the hands of older students, duly instructed in the process, the duty of taking sun pictures every clear noon. These records of the sun's condition, made by its own instantaneous impression, began as early as 1874."

Maria Mitchell was selected as President of "The American Association for the Advancement of Women," at the meeting in Syracuse of 1875, and again at the meeting in Philadelphia of 1876. And here again we discover a logical relation to the conditions of her early life. In what, long after, came to be called the "Woman's Movement," Miss Mitchell's mother had taken a decided interest, and lent to it her sympathy, at least to the extent that it sought to open to young women larger opportunities for earning their living by intelligent labor. It was, to this extent, in the very genius of Quakerism and consonant with its "Discipline." Miss Mitchell took many steps beyond her mother in this direction, but always with a quiet dignity that became one whose life presented an illustration of the loftiest purpose that the "movement" entertained.

Among her academic honors, she received her first degree, LL. D., from Hanover in 1853, and her last LL. D. from Columbia in 1887.

From the eloquent and sincere tribute paid to her memory by Dr. Taylor, the President of Vassar College, we quote the following as indicating the spirit of her example and teaching: —

"If I were to select for comment the one most striking trait of her character, I should name her genuineness. There was no false note in Maria Mitchell's thinking or utterance. Doubt she might, and she might linger in doubt, but false she could not be. Hers was a transparent character and her genuineness influenced her every word and deed. It was the key note of her independence; it was the deep source of her strength, and truth must be strong since God is truth. It was this perfect genuineness which gave her the strong hold she had on the admiration and affection of her students, — it was this in her which attracted most of those who loved her best. She fulfilled

the expectation of her friend, Dr. Channing, 'Worship God with what he most delights in, with aspiration for spiritual light and life.'

"But it would be vain for me to try to tell you just what it was in Miss Mitchell that attracted us who loved her; it was this combination of great strength and independence, of deep affection and tenderness, breathed through and through with the sentiment of a perfect life, which has made for us one of the pilgrim shrines of life the study in the Observatory of Vassar College, where we have known her at home surrounded by the evidences of her honorable professional career. She has been an impressive figure in our time, and one whose influence lives.

"This leads me to say a few words of her worth as a teacher. Her life became a strong influence in the lives of her devoted students. It was not that she impressed on them any peculiar views of hers; I have seen small evidence of that; but she wrought into their souls something of her own genuineness, her hatred for all shams in college, in social life, her love of truth, her honest search after it. Many are those who will carry her impress as long as they live, who gained from her a new inspiration, and who look back to that beautiful vine-clad observatory as a birthplace of new life in their souls. I feel the inadequacy of all I can say, as I think of the troop of young women grown to matronly dignity, teachers, wives, mothers, members of society, who would bid me say more, while she, in her simplicity of life and taste, would have me say far less.

"I have spoken as a friend of the traits of Maria Mitchell which have most impressed me in the three years of my close personal acquaintance with her. But I should not forget that I am the spokesman of others, of Trustees, and Faculty, and students of the College she served so faithfully. . . . A cloud of witnesses gathers about me, a great company of them have known and loved her, and have felt the power of her character and life."

Relative to the "doubts" referred to by Dr. Taylor, we remember them as self-conscious misgivings concerning another life. We do not remember that these misgivings ever included her father, whose cheerful faith and clear intellect, continuing to the last hour of his life, admitted only the transient shadow of an eclipse. Miss Mitchell once asked Mr. Whittier if he was perfectly confident of his immortality. The poet waived his own personal claims, and responded, "*I cannot conceive that the soul of Maria Mitchell can ever die.*"

After recording the generous appreciation that seemed to follow promptly upon every visible effort made by Miss Mitchell, and the

ample rewards she received, it would have been her wish, perhaps, that we should be content with this well balanced account; but remembering her quiet ways, her simple dress, and her scorn of self-indulgence, we feel that we ought to indicate by some sign the use she made of the earnings from her several employments. She had few ills of her own, but from her childhood she had been full of sympathy and tenderness for others who suffered. In her youth she gave to such *personal service*, out of the abundance of her strength, but later on she shared her *wages* with them, to a far greater advantage; and many now remember her best as the anxious friend who anticipated their wants.

Early in the winter of 1888, feeling that her strength was giving way, she resigned her chair at Vassar College, and retired as Professor Emerita. Other employments were relinquished. She returned to Lynn, and, after a very trying illness, she died there on the 28th of June of the same year.

THEODORE DWIGHT WOOLSEY.*

THEODORE DWIGHT WOOLSEY was born in the city of New York, October 31, 1801. Both his parents were of English descent. His father, a prominent and successful merchant, sprung from a family which was early settled on Long Island. His mother, a sister of the first President Dwight, was a granddaughter of Jonathan Edwards. He was doubly connected with President Dwight, whose wife was a sister of his father. The relatives of President Woolsey were stanch Federalists of the Hamilton school. This was one of the influences which gave a highly conservative tone to his political feeling. He always felt a strong antipathy to Jefferson and his ideas of government. He disbelieved in the doctrine of universal suffrage. Dr. Woolsey was graduated at Yale College in 1820, when he received the highest honors of the class. On leaving college he spent a year in the study of law in the office of Mr. Charles Chauncey of Philadelphia, — a fruitful year in its influence on his subsequent literary life. Deciding to enter the ministry, he joined the Princeton Theological Seminary, which he left at the end of a year to become a Tutor in Yale. This return to New Haven was in 1823. While holding this office, he studied during another year in the Yale Theological School. In 1825 he was licensed to preach; but a distrust

* Not ready in time for the preceding Annual Report.

of his capacity to realize his high ideal of the clerical office prevented him from making the ministry his life-work. His profound sense of religion was accompanied with an over-humble estimate of his own character and qualifications for the sacred calling. From 1827 to 1830 he was in Europe as a student; mainly in Germany, where he studied Greek philology under the great masters, Hermann, Boeckh, and Welcker. He became an adept in his chosen branch. Besides being accurate in the grammatical and lexical interpretation of the ancient authors, he entered with insight and deep appreciation into their literary qualities, and into the political and social life of antiquity. In the autumn of 1831, he commenced his career as Professor of Greek at Yale. He held this place until he was appointed, in 1846, President of the College. During this term of years, he published critical editions of a number of the Greek tragedies, and of the Gorgias of Plato. It is not too much to say that these publications mark an epoch in the history of classical studies in America. They were characterized by a more exact and scientific dealing with the ancient literature than had been the wont among us. On acceding to the Presidency, — an office to which he was chosen while he was travelling abroad, and which he reluctantly accepted, — he resigned the Greek department, and thenceforward taught to the senior classes history, political economy, and international law. At the beginning he was no novice in these branches, and his familiar acquaintance with the principal modern, as well as the ancient tongues, qualified him for the further study of them. His treatise on International Law, one of the products of this study, was designed as a text-book in colleges, but it was accepted at once as having a place among the authorities on the subject which it handled. It is more than an exposition in an orderly form of international usages; it is interspersed with ethical observations of a critical character, which had for their aim the improvement of the science.

Although Dr. Woolsey held no political office, he took a lively interest in national affairs. He avowed before the public, on all important occasions, his political opinions and preferences. He was consulted by the government in reference to important points connected with international differences.

When Dr. Woolsey became President, he was ordained as a Congregational minister, and frequently preached in the College chapel. His sermons, a selection of which was published, by their thoughtfulness and their religious earnestness made a strong impression on the academic audiences that listened to them. Through his life he was

a frequent contributor to the periodical press, especially to "The New-Englander," a review of which he was long one of the editors. In all his writings, President Woolsey aimed first and chiefly at clearness of expression. He detested the shows of rhetoric. But along with perspicuity and a homely force of diction, there is often an unsought beauty of illustration. He had a genuine delight in the masterpieces of poetry and art.

President Woolsey resigned the Presidency in 1871. Among his labors in the closing period of his life was the task of preparing for the press his copious and learned work on "Political Philosophy," — or the doctrine of rights and the State. The fact should not be omitted that he presided over the New Testament section of the American Revision Committee. All his life he was a student of the Scriptures. Nor did his studies lie in the New Testament alone. He was a Hebrew scholar, and read the ancient Scriptures in the original with facility. His theological learning was far from being limited to the exegetical department. In ecclesiastical history, especially, he was thoroughly informed. In truth, President Woolsey had an appetite for all good learning. His reading was extensive beyond the limits of the provinces which he most cultivated. When he read for recreation, he would sometimes have in his hand a poem in the Old French dialect, or a Greek play of Sophocles, or the Inferno of Dante, or the Politics of Aristotle in the original. Yet no one could be more free from the disposition to make a show of learning, or to win the applause which attainments so large naturally elicit. Soon after resigning the Presidency he printed a few copies, which were given to special friends, of a small collection of poems from his own pen.

In administering his office as President, he did a very important service in advancing the standards of scholarship, and in infusing, largely by his own example, thoroughness into all the departments of instruction. The College prospered remarkably under his care. Such were the dignity and earnestness of his character, his love of truth and his demand of truthfulness in others were so intense, and his abhorrence of everything base so consuming, that he drew to himself a respect that partook even of awe. Very few members of the numerous classes which he instructed failed to receive, as the result of their contact with him, lasting impressions of a most wholesome character. Rapid in his mental action, intolerant of indirection and of all disguises, with occupations that filled up his time, if he occasionally failed to hold a temper naturally quick under complete control, no one could be more grieved or more ready to make amends. It can

be truly said that the highest estimate of his moral excellence was formed by those who were brought into closest intercourse with him.

President Woolsey lived for eighteen years after he retired from the position of head of the College. His closing days were clouded with infirmities. He died on the 1st of July, 1889.

FOREIGN HONORARY MEMBER.

JAMES PRESCOTT JOULE.

James Prescott Joule was born at Salford, near Manchester, England, on December 25, 1818, the second of five children. As a lad he was so delicate that he was not sent to school, but was taught at home by tutors until he was about fifteen years of age, when he began to work in his father's brewery; and when the health of the father declined, the business fell entirely into the hands of young Joule and his brother Benjamin. The business made some knowledge of chemistry a necessity, and the two brothers were sent to Dalton, one of the most distinguished chemists that ever lived, to acquire it. Dalton at that time was President of the Manchester Literary and Philosophical Society, living and taking pupils at the Society's house in Manchester. The boys were taught arithmetic, algebra, and geometry at first, and afterwards natural philosophy and chemistry. For a text-book in chemistry Dalton used his own "New System of Chemical Philosophy." In 1837 Dalton's health became impaired so that he no longer received pupils, and it does not appear that Joule had any further school instruction. Dalton had introduced to his pupil physical and chemical apparatus, and had evidently taught him in some degree the art of experimentation. It is evident, too, that Joule was an apt scholar in that direction, for he at once began to experiment on his own account. He appropriated a room in his father's house, and enlarged his stock of apparatus mostly by his own constructions. There he began, in 1838, before he was twenty years of age, a series of investigations continued through his life, which for ingenuity, thoroughness, and scientific importance have not been exceeded by any one in this century. About an hundred titles of papers by him alone are on the list of the Royal Society of Great Britain, and twenty in conjunction with Thomson, Playfair, and Scoresby.

A distinguishing feature of the whole of Joule's work is his aim for quantitative results. His first work appears to have been upon

electro-magnetic engines, and his description of the mechanism and of its performance, as given in Sturgeon's "Annals of Electricity" in 1838 and after, show the definiteness of his ideas and of his work. For instance he tells how many grains his electro-magnets weighed, how many yards of silk-covered copper wire one fortieth of an inch in diameter were wound upon them, how many grains each magnet would hold up, how many revolutions per minute his engine made when supplied with electricity by one or more cells of battery, and how many pounds it was capable of raising one foot in a minute. Such painstaking to know the value and importance of every step in an inquiry is rare to-day, but it was much rarer fifty years ago; and to be found in a youth of twenty years, having no supervision and no incentive beyond his own impulses, is surprising indeed.

It is to be borne in mind, that in those days the so-called various forces, heat, light, electricity, magnetism, and chemism, were supposed to be independent forces; the idea of correlation among them had not dawned among physicists; much less had they any conception of what we call to-day the conservation of energy, which implies that all the various forms of energy are not only transformable into one another, but that they are so related quantitatively that the appearance of a definite quantity of one kind of energy implies the disappearance of an equal quantity of some other kind. Faraday indeed had already shown such a relation between chemism and electricity. Beyond that there was nothing done, and there were no fundamental ideas such as we to-day start with. When, therefore, we find young Joule measuring the work done by an electric motor in foot pounds, and comparing the result with the amount of zinc dissolved in his battery, it is easy to see how far ahead of his contemporaries he was. From his experiments with batteries and his electro-magnetic engines in 1839 and 1840, he concludes that galvanic batteries using zinc cannot be made to compete with steam-engines using coal as sources of power. His conclusions still hold good after the lapse of fifty years, and the experience of a multitude of experimenters, some of whom continue to work and hope that the laws involved are not so rigorous as Joule supposed.

In 1841 he discovered that a bar of iron was elongated when it was magnetized, and he measured the amount of the elongation, finding it to be the one thirty-thousandth part of an inch in a bar two feet long when magnetized with the current from five Grove cells.

In 1840 he presented a paper to the Royal Society containing an investigation into the distribution of heat in an electric circuit, wherein

he concludes that the heat produced is proportional to the resistance of the conductor, independent of the shape or kind of metal which closes the circuit. He proved also that the "heat evolved in a given time is proportional to the resistance of the conductor multiplied by the square of the electric intensity." By electric intensity he meant what we now call current, and the above we now recognize as RC^2.

In the early part of the century, Davy and Count Rumford had proved from their experiments that heat was but a kind of molecular motion, not an entity as had long been supposed, but this conception did not become general among those who had most to do with thermal phenomena. Text-books, as well as special treatises, continued to represent the old conceptions as yet valid till within about twenty-five years. Nowadays we are so familiar with the expression "heat as a mode of motion" that few give to it more than a passing thought, and a large number of persons who deal with the subject of heat in its mechanical relations speak of it as a "form of energy," an expression which fails to convey with any definiteness the character of the motions that differentiate heat from other kinds of energy motion. As energy is a product with motion as one of the factors, it follows that a *mode of motion* and a *form of energy* cannot be identical. Joule was not muddled on that. In 1843 he read a paper before the British Association on the "Mechanical Value of Heat." In that paper he says, "When we consider heat not as a *substance*, but as a *state of vibration*, there appears to be no reason why it should not be induced by an action of a simply mechanical character." The Italics are his. He then describes at length numerous experiments in which the heat developed in an electric circuit was measured, when the electric current was produced by a magneto-electric machine. The amount of work required to turn the magneto-electric machine when producing the current was carefully measured also, and from these he reached the first determination of the mechanical equivalent of heat, namely. "*The quantity of heat capable of increasing the temperature of a pound of water by one degree of Fahrenheit's scale is equal to, and may be converted into, a mechanical force capable of raising* 838 *pounds to the perpendicular height of one foot.*" This result, as we now know, is too large, and in 1881 he accounted for the excess by noting that no allowance was made for the heat absorbed by the magnet itself, which at first he thought neglectable; but at the latter date he concludes it would account for all the difference between 838 and 772.

The story of the reception of this remarkable paper by British physicists, giving as it did the first law of thermodynamics, is strik-

ing. It was read before the Chemical Section of the British Association Meeting at Cork, on the 21st of August, 1843. Some of the members of the Royal Society expressed the opinion that it was nonsense from beginning to end, that the author must live in some benighted region, that the imponderables could not be expressed in foot pounds, etc., and as a body they refused to publish it in their Transactions. Sir William Thomson in 1847, though not entirely persuaded of the truth of Joule's conclusions, seems to have been the only one to show any degree of friendliness to them, and he advised moderation in the condemnation; nevertheless, the paper was not published by the Society until 1850, seven years after its presentation.*

Sir H. E. Roscoe said, when referring to the reception of this epoch-making paper of 1843, that "the men who so bitterly opposed it ought to have known better." But it is certain that they had been taught differently, and when one has achieved distinction in physical science he is likely to possess his own philosophy of things, in which not a small part of the data is symbolic, and is represented in mind only by a name, and if this name chances to suggest something mysterious, as, for instance, an imponderable, the less is one likely to attempt or suffer others to attempt to displace it by definite mechanical conceptions. To change one's fundamental conceptions necessitates a change in his philosophy,—a change that is not only difficult, but highly distasteful, to everybody; hence one could hardly expect much of a welcome to a man whose work demanded such a change; and this was the case with Joule, as it was with Galileo, with Newton, with Laplace, Young, and Faraday.

His inquiries thus far had led him to the examination of the quantitative relations not only existing between heat and so-called mechanical motion, but also those existing between chemical affinities, electricity, and magnetism,—in fact, between all the forms of energy in inorganic phenomena; and for these he was able to show a mechanical equivalent, in such a way as to make it certain that the only difference between the so-called forces of those days was a difference in the character of the motions the bodies that exhibited the forces had. In this body, all the molecules are moving in one direction at a certain rate, and we call it mechanical motion. In another body, the molecules are individually vibrating while the body as a whole does

* In 1849 he presented a paper to the British Association upon the same subject, which was printed, except the following proposition, which the committee was unwilling to publish. "Friction consists in the conversion of mechanical power into heat." (!)

not change its position, and this we call heat; but when the sum of the individual motions is equal to the motions of the first body, the two bodies have the same amount of energy. One condition we call mechanical, the other heat. In a proper sense they may all be called mechanical conditions, but it is convenient to designate the varieties by different names. Joule evidently saw this at the outset, for his experiments were all devised to fit such hypothetical conditions, and they therefore show how clear his mechanical conceptions were, and how far in advance he was of any of his contemporaries.

His experiments upon the mechanical equivalent of heat were continued from year to year for a long time. In 1847 he had reduced the equivalent to 781.8, and in 1849 to 772 foot pounds, the same number we use to-day. He followed out the fundamental idea in all sorts of ingenious ways; by friction in water, in oil, in mercury, in the velocity of sound in air, in determining the velocity of a molecule of hydrogen under standard conditions of temperature and pressure, in calculating specific heats, in the efficiency of steam and air engines, the effects of pressure, and the temperature of meteors while passing through the atmosphere. By 1852, however, Joule's work became pretty generally known in Europe, and he had been elected a member of numerous societies there before he had been thus honored at home. It was the old story. The wise man lives in the next town, he is not our neighbor. While the learned of Europe were honoring him, the people of Manchester were asking, "Who is this Joule of Manchester we are hearing about?"

In 1864 he was made one of the Committee of the British Association to devise a system of electrical units, which gave us the volt, the ohm, and the rest of the unit terminology so indispensable now. In his earliest work, it was necessary for him to know with greater definiteness than was possible with such a system as was then in use, or rather the lack of it, and he devised one which is easily transformed into the absolute one we now employ, and his services in that committee were invaluable. The determination of the ohm resulted in a larger figure for the mechanical equivalent of heat than Joule had found in other ways, and he offered to change its value to correspond; but it afterwards appeared that his value was nearer right than the new one thus obtained. In 1878 his determination of this quantity was 772.55 pounds. This mechanical equivalent is sometimes called a Joule, and has J for its symbol in honor of the discoverer.

The statement of the relationship between heat and work is the

first law of thermodynamics and is framed in various ways by different authors.

Joule was married in 1847, but his wife died in 1854, leaving him a son and a daughter.

As to his character it appears that he was not a public man. He had but few acquaintances. His interests were with his apparatus in his laboratory. He had a rare way of interrogating Nature, so that her answers were not enigmatical, as they often are to less gifted men. The outcome of his work is of such a character as to quite transform all our conceptions of the order and precedence of things physical in the heavens and in the earth. It has given us the new and fundamental science of thermodynamics, and has necessitated the rewriting of all philosophy.

The Physical Society of London has published a collected edition of his works. In 1878 he was granted a pension of £200 per year, and he also received several gold medals in recognition of his labors. He died on October 11, 1889. Steps were taken at once to raise a national memorial to him in the city of Manchester.

The Academy has received an accession of twelve members, — four Resident Fellows, seven Associate Fellows, and one Foreign Honorary Member.

Two Resident Fellows have been elected to fill vacancies in the list of Associate Fellows, and two Resident Fellows have resigned.

The roll of the Academy, corrected to February 15, 1891, includes the names of 186 Resident Fellows, 93 Associate Fellows, and 74 Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

(Corrected to February 15, 1891.)

RESIDENT FELLOWS.—186.

(Number limited to two hundred.)

CLASS I.—*Mathematical and Physical Sciences.*—77.

SECTION I.—6.

Mathematics.

Gustavus Hay,	Boston.
Benjamin O. Peirce,	Cambridge.
James M. Peirce,	Cambridge.
John D. Runkle,	Brookline.
T. H. Safford,	Williamstown
William E. Story,	Worcester.

SECTION II.—10.

Practical Astronomy and Geodesy.

Seth C. Chandler,	Cambridge.
Alvan G. Clark,	Cambridgeport.
George B. Clark,	Cambridgeport.
J. Rayner Edmands,	Cambridge.
Henry Mitchell,	Boston.
Edward C. Pickering,	Cambridge.
John Ritchie, Jr.,	Boston.
Edwin F. Sawyer,	Brighton.
Arthur Searle,	Cambridge.
O. C. Wendell,	Cambridge.

SECTION III.—46.

Physics and Chemistry.

A. Graham Bell,	Washington.
Clarence J. Blake,	Boston.
Francis Blake,	Weston.
John H. Blake,	Boston.
Arthur M. Comey,	Somerville.
Josiah P. Cooke,	Cambridge.
James M. Crafts,	Boston.
Charles R. Cross,	Boston.
Amos E. Dolbear,	Somerville.
Thos. M. Drown,	Boston.
Charles W. Eliot,	Cambridge.
Moses G. Farmer,	Eliot, Me.
Thomas Gaffield,	Boston.
Wolcott Gibbs,	Newport, R. I.
Edwin H. Hall,	Cambridge.
Henry B. Hill,	Boston.
N. D. C. Hodges,	New York.
Silas W. Holman,	Boston.
William L. Hooper,	Somerville.
Eben N. Horsford,	Cambridge.
T. Sterry Hunt,	New York.
Charles L. Jackson,	Cambridge.
William W. Jacques,	Newton.
Alonzo S. Kimball,	Worcester.
Leonard P. Kinnicutt,	Worcester.
William R. Livermore,	Newport, R.I.
Joseph Lovering,	Cambridge.
Charles F. Mabery,	Cleveland.
Arthur Michael,	Worcester.
A. A. Michelson,	Worcester.
Charles E. Munroe,	Newport, R.I.
John U. Nef,	Worcester.
Lewis M. Norton,	Newton.
Robert H. Richards,	Boston.
Theodore W. Richards,	Cambridge.
Edward S. Ritchie,	Brookline.
A. Lawrence Rotch,	Boston.
Charles R. Sanger,	Cambridge.
Stephen P. Sharples,	Cambridge.
Francis H. Storer,	Boston.
Elihu Thomson,	Lynn.
John Trowbridge,	Cambridge.
Cyrus M. Warren,	Brookline.
Harold Whiting,	Cambridge.
Charles H. Wing,	Boston.
Edward S. Wood,	Cambridge.

Section IV. — 15.

Technology and Engineering.

John M. Batchelder,	Cambridge.
Winfield S. Chaplin,	Cambridge.
Eliot C. Clarke,	Boston.
James B. Francis,	Lowell.
Gaetano Lanza,	Boston.
E. D. Leavitt,	Cambridgeport.
William R. Lee,	Roxbury.
Hiram F. Mills,	Lawrence.
Cecil H. Peabody,	Boston.
Alfred P. Rockwell,	Boston.
Peter Schwamb,	Boston.
Charles S. Storrow,	Boston.
George F. Swain,	Boston.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

Class II. — *Natural and Physiological Sciences.* — 57.

Section I. — 8.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
Algernon Coolidge,	Boston.
William O. Crosby,	Boston.
William M. Davis,	Cambridge.
O. W. Huntington,	Cambridge.
Jules Marcou,	Cambridge.
William H. Niles,	Cambridge.
Nathaniel S. Shaler,	Cambridge.

Section II. — 6.

Botany.

William G. Farlow,	Cambridge.
George L. Goodale,	Cambridge.
H. H. Hunnewell,	Wellesley.
Charles S. Sargent,	Brookline.
Charles J. Sprague,	Boston.
Sereno Watson,	Cambridge.

Section III. — 21.

Zoölogy and Physiology.

Alex. E. R. Agassiz,	Cambridge.
Robert Amory,	Boston.
James M. Barnard,	Milton.
Henry P. Bowditch,	Boston.
Edward Burgess,	Boston.
Harold C. Ernst,	Boston.
J. Walter Fewkes,	Boston.
Hermann A. Hagen,	Cambridge.
Samuel Henshaw,	Cambridge.
Alpheus Hyatt,	Cambridge.
Theodore Lyman,	Brookline.
Edward L. Mark,	Cambridge.
Charles S. Minot,	Boston.
Edward S. Morse,	Salem.
James J. Putnam,	Boston.
Samuel H. Scudder,	Cambridge.
William T. Sedgwick,	Boston.
D. Humphreys Storer,	Boston.
Henry Wheatland,	Salem.
James C. White,	Boston.
Charles O. Whitman,	Worcester.

Section IV. — 22.

Medicine and Surgery.

Samuel L. Abbot,	Boston.
Henry I. Bowditch,	Boston.
Edward H. Bradford,	Boston.
Arthur T. Cabot,	Boston.
David W. Cheever,	Boston.
Benjamin E. Cotting,	Roxbury.
Frank W. Draper,	Boston.
Thomas Dwight,	Boston.
Reginald H. Fitz,	Boston.
Charles F. Folsom,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
John Homans,	Boston.

Alfred Hosmer,	Watertown.
Frederick I. Knight,	Boston.
George H. Lyman,	Boston.
Francis Minot,	Boston.
Wm. L. Richardson,	Boston.
George C. Shattuck,	Boston.
Henry P. Walcott,	Cambridge.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

Class III. — *Moral and Political Sciences.* — 52.

Section I. — 9.

Philosophy and Jurisprudence.

James B. Ames,	Cambridge.
Phillips Brooks,	Boston.
Charles C. Everett,	Cambridge.
Horace Gray,	Boston.
John C. Gray,	Boston.
Nathaniel Holmes,	Cambridge
John Lowell,	Newton.
Henry W. Paine,	Cambridge.
James B. Thayer,	Cambridge.

Section II. — 17.

Philology and Archæology.

William S. Appleton,	Boston.
Lucien Carr,	Cambridge.
Franklin Carter,	Williamstown.
Joseph T. Clarke,	Boston.
Henry G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Quincy.
William W. Goodwin,	Cambridge.
Henry W. Haynes,	Boston.
Bennett H. Nash,	Boston.
Frederick W. Putnam,	Cambridge.
F. B. Stephenson,	Boston.
Joseph H. Thayer,	Cambridge.
Crawford H. Toy,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
Edward J. Young,	Waltham.

Section III. — 16.

Political Economy and History.

Charles F. Adams,	Quincy.
Edward Atkinson,	Boston.
John Cummings,	Woburn.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
Henry C. Lodge,	Boston.
Augustus Lowell,	Boston.
Edward J. Lowell,	Boston.
Francis Parkman,	Boston.
Andrew P. Peabody,	Cambridge.
John C. Ropes,	Boston.
Denman W. Ross,	Cambridge.
F. W. Taussig,	Cambridge.
Henry W. Torrey,	Cambridge.
Francis A. Walker,	Boston.
Robert C. Winthrop,	Boston.

Section IV. — 10.

Literature and the Fine Arts.

George S. Boutwell,	Groton.
Martin Brimmer,	Boston.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Charles G. Loring,	Boston.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
Horace E. Scudder,	Cambridge.
Barrett Wendell,	Boston.
John G. Whittier,	Amesbury.

ASSOCIATE FELLOWS. — 93.

(Number limited to one hundred.)

Class I. — *Mathematical and Physical Sciences* — 36.

Section I. — 6.

Mathematics.

William Ferrel, Martinsburg, Va.
Thomas Hill, Portland, Me.
Simon Newcomb, Washington.
H. A. Newton, New Haven.
James E. Oliver, Ithaca, N.Y.
J. N Stockwell, Cleveland.

Section II. — 12.

Practical Astronomy and Geodesy.

W. H C Bartlett, Yonkers, N.Y.
S. W. Burnham, San José, Cal.
Geo. Davidson, San Francisco.
Wm. H. Emory, Washington.
Asaph Hall, Washington.
J. E. Hilgard, Washington.
George W. Hill, Washington.
E. S. Holden, San José, Cal.
Sam. P. Langley, Washington.
William A. Rogers, Waterville, Me.
George M. Searle, New York.
Chas. A. Young, Princeton, N.J.

Section III. — 12.

Physics and Chemistry.

Carl Barus, Washington.
J. Willard Gibbs, New Haven
Frank A. Gooch, New Haven.
S. W. Johnson, New Haven.
M. C. Lea, Philadelphia.
John Le Conte, Berkeley, Cal.
J. W. Mallet, Charlottesville, Va.
A. M. Mayer, Hoboken, N. J.
Ira Remsen, Baltimore.
Ogden N. Rood, New York.
H. A. Rowland, Baltimore.
L. M Rutherfurd, New York.

Section IV. — 6.

Technology and Engineering.

Henry L. Abbot, New York.
Geo. W. Cullum, New York.
Geo. S. Morison, New York.
John Newton, New York.
William Sellers, Philadelphia.
W. P. Trowbridge, New Haven.

Class II. — *Natural and Physiological Sciences* — 30.

Section I. — 14.

Geology, Mineralogy, and Physics of the Globe.

Cleveland Abbe, Washington.
George J. Brush, New Haven.
James D. Dana, New Haven.
Sir J. W. Dawson, Montreal.
F. A. Genth, Philadelphia.
James Hall, Albany, N Y
F. S. Holmes, Charleston, S. C.
Clarence King, New York
Joseph Le Conte, Berkeley, Cal.
J. Peter Lesley, Philadelphia.
J. S. Newberry, New York.
J. W. Powell, Washington.
R. Pumpelly, Newport, R.I.
Geo. C. Swallow, Columbia, Mo.

Section II. — 2.

Botany.

A W Chapman, Apalachicola, Fla.
D. C. Eaton, New Haven.

Section III. — 8.

Zoölogy and Physiology.

Joel A. Allen, New York.
G. B. Goode, Washington.
Joseph Leidy, Philadelphia.
O. C. Marsh, New Haven.
H. N. Martin, Baltimore.
S. Weir Mitchell, Philadelphia.
A. S. Packard, Providence.
A. E. Verrill, New Haven.

Section IV. — 6.

Medicine and Surgery.

Fordyce Barker, New York.
John S. Billings, Washington.
Jacob M. Da Costa, Philadelphia.
W. A. Hammond, New York.
Alfred Stillé, Philadelphia.
H. C. Wood, Philadelphia.

Class III. — *Moral and Political Sciences.* — 27.

Section I. — 8.

Philosophy and Jurisprudence.

T. M. Cooley, Ann Arbor, Mich.
D. R. Goodwin, Philadelphia.
A. G. Haygood, Oxford, Ga
James McCosh, Princeton, N.J
Charles S. Peirce, New York.
Noah Porter, New Haven.
E. G. Robinson, Providence.
Jeremiah Smith, Dover, N.H.

Section II. — 7.

Philology and Archæology.

A. N. Arnold, Pawtuxet, R.I.
Timothy Dwight, New Haven.
D. C. Gilman, Baltimore.
A. C. Kendrick, Rochester, N.Y.
E. E. Salisbury, New Haven.
A. D. White, Ithaca, N.Y.
W. D. Whitney, New Haven.

Section III. — 6.

Political Economy and History.

Henry Adams, Washington.
M F. Force, Cincinnati.
Henry C. Lea, Philadelphia.
Edward J. Phelps, Burlington, Vt.
W. G. Sumner, New Haven.
J. H. Trumbull, Hartford.

Section IV. — 6.

Literature and the Fine Arts.

James B. Angell, Ann Arbor, Mich.
L. P. di Cesnola, New York.
F. E. Church, New York.
R. S. Greenough, Florence.
William W. Story, Rome.
Wm. R. Ware, New York.

FOREIGN HONORARY MEMBERS.—74.

(Elected as vacancies occur.)

Class I.—*Mathematical and Physical Sciences.*—26.

Section I.—6.

Mathematics.

John C. Adams,	Cambridge.
Sir George B. Airy,	London.
Francesco Brioschi,	Milan.
Arthur Cayley,	Cambridge.
Charles Hermite,	Paris.
J. J. Sylvester,	Oxford.

Section II.—5.

Practical Astronomy and Geodesy.

Arthur Auwers,	Berlin.
J. H. W. Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
Eduard Schönfeld,	Bonn.
Otto Struve,	Pulkowa.

Section III.—12.

Physics and Chemistry.

Adolf Baeyer,	Munich.
Marcellin Berthelot,	Paris.
R. Bunsen,	Heidelberg.
H. L. F. Helmholtz,	Berlin.
A. W. Hofmann,	Berlin.
Mendeleeff,	St. Petersburg.
Marignac,	Geneva.
Lord Rayleigh,	Witham.
Sir H. E. Roscoe,	London.
G. G. Stokes,	Cambridge.
Julius Thomsen,	Copenhagen.
W. E. Weber,	Göttingen.

Section IV.—3.

Technology and Engineering.

Marquis de Caligny,	Versailles.
F. M. de Lesseps,	Paris.
Sir Wm. Thomson,	Glasgow.

Class II.—*Natural and Physiological Sciences.*—27.

Section I.—6.

Geology, Mineralogy, and Physics of the Globe.

H. Ernst Beyrich,	Berlin.
Alfred Des Cloizeaux,	Paris.
A. E. Nordenskiöld,	Stockholm.
C. F. Rammelsberg,	Berlin.
Sir A. C. Ramsay,	Beaumaris.
Heinrich Wild,	St. Petersburg.

Section II.—7.

Botany.

J. G. Agardh,	Lund.
Alphonse de Candolle,	Geneva.
Sir Joseph D. Hooker,	London.
C. J. Maximowicz,	St. Petersburg.
Carl Nägeli,	Munich.
Julius Sachs,	Würzburg.
Marquis de Saporta,	Aix.

Section III. — 10.

Zoölogy and Physiology.

P. J. Van Beneden,	Louvain.
Du Bois-Reymond,	Berlin.
Thomas H. Huxley,	London.
Albrecht Kölliker,	Würzburg.
Lacaze-Duthiers,	Paris.
Rudolph Leuckart,	Leipsic.
C. F. W. Ludwig,	Leipsic.
Sir Richard Owen,	London.
Louis Pasteur,	Paris.
J. J. S. Steenstrup,	Copenhagen.

Section IV. — 4.

Medicine and Surgery.

Sir Wm. Bowman,	London.
C. E. Brown-Séquard,	Paris.
Sir James Paget,	London.
Rudolph Virchow,	Berlin.

Class III. — *Moral and Political Sciences.* — 21.

Section I. — 3.

Philosophy and Jurisprudence.

James Martineau,	London.
Henry Sidgwick,	Cambridge.
Sir James F. Stephen,	London.

Section II. — 7.

Philology and Archæology.

John Evans,	Hemel Hempstead.
Pascual de Gayangos,	Madrid.
Benjamin Jowett,	Oxford.
J. W. A. Kirchhoff,	Berlin.
G. C. C. Maspero,	Paris ?
Max Müller,	Oxford.
Sir H. C. Rawlinson,	London.

Section III. — 7.

Political Economy and History.

Duc de Broglie,	Paris.
Ernst Curtius,	Berlin.
W. Ewart Gladstone,	London.
Charles Merivale,	Ely.
Theodor Mommsen,	Berlin.
Jules Simon,	Paris.
William Stubbs,	Chester.

Section IV. — 4.

Literature and the Fine Arts.

Jean Léon Gérôme,	Paris.
John Ruskin,	Coniston.
Leslie Stephen,	London.
Lord Tennyson,	Isle of Wight.

INDEX.